OF THE

MENSURATION

OF

RUNNING WATERS.

An Excellent Piece

Written in ITALIAN

BY

DON BENEDETTO CASTELLI,
Abbot of St. *BENEDETTO ALOYSIO*,
and Profeſſour of the Mathematicks to
Pope *URBAN VIII.* in *ROME*.

Engliſhed from the Third and beſt Edition, with the addition of a Second Book not before extant:

By *THOMAS SALUSBURY*.

LONDON,
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THE AUTHOURS EPISTLE TO Pope VRBAN VIII.

I Lay at the Feet of your Holineſſe theſe my Conſiderations concerning the MENSURATION OF RUNNING WATERS: Wherein if I ſhall have ſucceeded, being a matter ſo difficult and unhandled by Writers both Ancient Modern, the diſcovery of any thing of truth hath been the Effect of Your Holineſſes Command; and if through inability I have miſſed the Mark, the ſame

Command will ſerve me for an Excuſe with Men of better Judgment, and more eſpecially with Your Holineſſe, to whom I humbly proſtrate my ſelf, and kiſſe Your Sacred Feet.

From ROME.

Your Holineſſes

Moſt humble Servant

BENEDETTO.

A Monk of *Caſſino.*

AN ACCOUNT OF THE Authour and Work.

DON BENEDETTO CASTELLI, *the famous Authour of these ensuing Discourses of the* Mensuration of Running Waters, *is descended from the Worshipful FAMILY of the* CASTELLII, *and took his first breath near to the lake* THRASIMENUS, (*where* Hanibal *gave a fatal overthrow to the* Roman *Legions*) *in that sweet and fertile part of happy* ITALY, *called the* Territory *of* PERUGIA, *a branch of the Dukedome of* TUSCANY, *which at present submitteth to the Jurisdiction of the Church, as being a part of* St. PETER'S Patrimony. *His Parents, who were more zealous of the good of his Soul than observant of the Propension of his Genius, dedicated him (according to the Devotion of that Country) to the Service of the Church; and entered him into the Flourishing Order of Black-Friers, called from the place Moncks of* Monte Casino, *and from the Founder* Benedictines. *Nature, that She might consummate the Profusion of her Favours upon him, sent him into the World in an Age that was so ennobled and illuminated with Eminent Scholars in all Kinds of Literature, that hardly any Century since the Creation can boast the like.*

§. *In particular, the* SCIENCES MATHEMATICAL *had then got that Fame and Esteem in the Learned World, that all men of Spirit or Quality became either Students in, or Patrons of those Sublime Knowledges. On this occasion the Curiosity of our* AUTHOUR *being awakened, his Active Wit could not endure to be any longer confined to the Slavish Tuition of Hermetical Pedagogues; but in concurrence with the Genius of the Age, he also betook himself to those most Generous and Liberal Studies. His helps in this his design were so many, and so extraordinary, that had his Inclination been weaker, or his Apprehension lesser, he could hardly have failed attaining more than a Common Eminency in these Sciences. For besides the Deluge of Learned and Useful Books, which the Presse at that time sent forth from all parts of* EUROPE, *he had the good Fortune to fall into the Acquaintance, and under the Instruction of the most Demonstrative and most Familiar Man in the World, the Famous* GALILEO: *whose successe being no lesse upon this his* Pupil *than upon the rest of those Illustrious and Ingenious Persons that resorted from all parts to sit under his Admirable Lectures, he in a short time attained to that Name in the Mathematicks, that he was invited to* ROME, *Complemented, and Preferred by his then Holinesse the Eighth* URBAN, *upon his very first Accession to the* Papacy, *which was in the Year* 1623.

§. *This Pope being moved with a Paternal Providence for the Concerns of his Subjects in that part of* ITALY *about* BOLOGNA, FERRARA, *and* COMMACHIO, *lying between the Rivers of* PO *and* RENO, *which is part of* Lo Stato della Chiesa, *or the Church Patrimony, appoints this our* CASTELLI *in the Year* 1625, *to accompany the Right Honourable* Monsignore GORSINI (*a most observant and intelligent person in these affaires, and at that time Superintendent of the General Draines, and President of* ROMAGNA) *in the Grand Visitation which he was then ordered to make concerning the disorders occasioned by the Waters of those parts.*

§. CASTELLI, *having now an Opportunity to employ, yea more, to improve such Notions as he had imbued from the Lectures of his Excellent* MASTER, *falls to his work with all industry: and in the time that his Occasions detained him in* ROMAGNA *he perfected the First Book of this his Discourse concerning the* Mensuration of Running Waters. *He confesseth that he had some years before applyed himself to this part of* Practical Geometry, *and from several Observations collected part of that Doctrine which at this time he put into Method, and which had procured him the Repute of so much Skill that he began*

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to be Courted by ſundry Princes, and great Prelates. In particular about the beginning of the Year 1623. *and before his Invitation to* ROME *he was employed by Prince* Ferdinando I, *Grand Duke of* TUSCANY, *to remedy the Diſorders which at that time happened in the Valley of* PISA *in the Meadows that lye upon the Banks of* Serchio *and* Fiume Morto: *and in the preſence of the Grand Duke, Grand Dutcheſſe Mother, the Commiſſioners of Sewers, and ſundry other Perſons in a few hours he made ſo great a progreſſe in that affair, as gave his Moſt Serene Highneſſe high ſatisfaction, and gained himſelf much Honour.*

§. *No ſooner had he in his fore-mentioned Voiage to* ROMAGNA *(which was but few Moneths after, in the ſame Year) committed his Conceptions to paper, but he communicated them to certain of his Friends. In which number we finde* Signore Ciampoli *Secretary of the Popes Private Affaires; whom in the beginning of the Firſt Book he gratefully acknowledgeth to have been contributary, in his Purſe, towards defraying the charge of Experiments, and in his Perſon, towards the debating and completing of Arguments upon this Subject. Some few years after the importunity of Friends, and the Zeal he had for the Publique Good prevailed with him to preſent the World with his Firſt Diſcourſe, accompanied with a Treatiſe of the Geometrical Demonſtrations of his whole* Doctrine. *What Reception it found with the Judicious muſt needs be imagined by any one that hath obſerved how* Novelty *and* Facility *in conjunction with* Verity *make a Charm of irreſiſtable Operation.*

§. New *it was, for that no man before him had ever attempted to* Demonſtrate *all the three* Dimenſions, *to wit, the Length, Breadth and Profundity, of this Fluid and Current Element. And he detecteth ſuch groſſe Errours in thoſe few that had untertook to write upon the Subject (of which he inſtanceth in* Frontinus *and* Fontana, *as thoſe that include the reſt) and delivereth ſuch ſingular and unheard-of Paradoxes (for ſo they ſound in Vulgar Eares) as cannot but procure unſpeakable delight to his Reader.*

§. Eaſie *it is likewiſe and* True; *and that upon ſo Familiar Experiments and Manifeſt* Demonſtrations, *that I have oft queſtioned with my ſelf which merited the greater wonder, he, for diſcovering, or all men that handled the Argument before him for not diſcovering a* Doctrine *of ſuch ſtrange Facility and Infallibility. But yet as if our Authour deſigned to oblige the whole World to him by ſo excellent a* Preſent, *he ſelects a Subject that he knew would be carreſſed by all perſons of Nobler Souls, upon the accounts afore-named, and by all Mankind in General, as gratifying them in their much adored Idol* Utility. *And to ren-*

der

der his Art the more profitable, he reduceth the lofty, and easie-to-be-mistaken Speculations of the Theory, into certain and facile Directions for Practice; teaching us how to prevent and repaire the Breaches of Seas, and Inundations of Rivers; to draine and recover Fenns and Marches; to divert, conveigh and distribute Waters for the Flowing and Stercoration of Grounds, strengthening of Fortifications, serving of Aquaducts, preserving of Health (by cleansing Streets, and scowring Sewers) and maintaining of Commerse (by defending Bridges, cleering Rivers, and opening Ports and Channels) with innumerable other Benefits of the like nature. And, that I may omit no circumstance that may recommend my Authour, the Fortune of this his Treatise hath been such, that as if he intended a Plus ultra *by it, or as if all men despaired to out-do it, or lastly, as if* CASTELLI *hath been so great a* Master *that none have presumed to take Pencil in hand for the finishing of what he* Pourfoild, *this small Tract like the Arabian Phœnix (of which it is said* Unica semper Avis) *did for several years together continue single in the World, till that to verifie it to be truly* Phœnician, *it renewed its Age by undergoing a second Impression. And as if this did not make out the Immortal vertue of it, it hath had* Anno 1660 *a third Circulation, and risen in this last Edition as it were from the Urne of its Authour; and that so improved by the Addition of a second part, that it promiseth to perpetuate his Merits to all Posterity. To be brief, the meer Fame of this Work resounded the Honourable Name of* CASTELLI *into all the Corners of* Italy, *I may say of* Europe; *insomuch, that, in hopes to reap great benefit by his Art, the respective Grandees of the adjacent Countries courted his Judgment and Advice about their* Draining of Fenns, Diversion of Rivers, Evacuation of Ports, Preventing of Inundations, &c. *So that every Summer he made one or more of these Journies or Visitations. Particularly, the* Senate *of* Venice *consulted him about their Lake; to whom he delivered his Opinion in* May 1641. *and upon farther thoughts he presented them with another Paper of Considerations the* 20 December *following. Prince* LEOPOLDO *of* TUSCANY *likewise requested his Advice in the beginning of the ensuing year* 1642, *which occasioned his Letter to Father* Francesco di San Giuseppe, *bearing date* February 1, *To which* Signore Bartolotti *opposing, he writes a second Letter, directed to one of the Commissioners of* Sewers, *vindicating his former, and refuting* Bartolotti, *both which I here give you.*

§. *The Preferments which his Merits recommended him unto, were first to be Abbot of* Cassino, *from which he was removed*

Anno

Anno 1640, *or thereabouts, unto the Abbey of* Santo Benedetto Aloysio; *and much about the same time preferred to the Dignity of Chief Mathematician to his grand Patron Pope* URBAN VIII. *and Publique Professour of Mathematicks in the University of* ROME.

§. *Here a Stop was put to the Carier of his Fortunes, and being fuller of Honour than of Years, was by Death, the Importunate Intrerupter of Generous Designs, prevented in doing that farther Good which the World had good reason to promise it self from so Profound and Industrious a Personage, leaving many Friends and Disciples of all Degrees and Qualities to lament his losse, and honour his Memory.*

§. *His singular Virtues and Abilities had gained him the Friendship of very many; as to instance in some, he had contracted strict Amity with* Monsignore Maffei Barberino *a Florentine, Præfect of the Publique Wayes, and afterwards Pope with the Name of* URBAN VIII. *as was said before; with the above-named* Monsignore Corsini *Superintendant of the General Draines: with* Monsignore Piccolomini *Arch-Bishop of* Siena: *with Cardinal* Serra: *with Cardinal* Caponi, *who hath studied much and writ well upon this Subject; and with Cardinal* Gaetano *who frequently consulted with him in his design of Draining the Fenns of* ROMAGNA. *Moreover Prince* LEOPOLDO, *and his Brother the Grand Duke had very great kindnesse for him; which speaks no small attractions in him, considering him as a favourite of the Family of* Barberini, *between whom and the House of* Medeci *there is an inveterate Fewd. Amongst persons of a lower Quality he acknowledgeth* Signore Ciampoli *the Popes Secretary,* Sig. Ferrante Cesarini, Sig. Giovanni Basadonna *Senator of* Venice; *and I find mentioned* Sig. Lana, Sig. Albano, Padre Serafino, Pad. Francesco de San. Giuseppe, *and many others.*

§. *The Works in which he will survive to all succeeding Ages are first His solid and sober Confutation of the Arguments of* Signore Lodovico dell Columbo, *and* Signore Vincentio di Gratia *against the Tract of* Galileo Delle cose che stanno sopra Aqua, *wherein he vindicates his said* Master *with a Gratitude that Tutors very rarely reap from the pains they take in Cultivating their* Pupils. *This Apology was first Printed* Anno 1615. *and was a second time published, as also those of his Antagonists, amongst the Works of* GALILEO, *set forth by the Learned* Viviani 1656. *He hath likewise writ several other curious Pieces, as I am informed by the most Courteous* Carolo Manolessi *of* Bologna; *amongst others an excellent Treatise concerning* Colours, *which he putteth me in hopes to see printed very*

very ſpeedily. And laſt of all theſe Diſcourſes and Reflections upon the Menſuration of Running Waters, *with the addition of a Second Book, three Epiſtles, and four Conſiderations upon the ſame Argument, which conduce much to Illuſtrate his Doctrine and Facilitate the Practice of it; and which with a Relation of* Monſignore Corſini, *make the ſecond part of my Firſt Tome.*

§. *I might here ſally forth into the Citation of ſundry Authours of Good Account, that have tranſmitted his Character to Poſterity, but ſhall confine my ſelf to onely two; the one is of his* Maſter, *the other of his* Scholar; *than whom there cannot be two more competent Judges of his Accompliſhments. To begin with his* Maſter, *the Quick-ſighted, and truly Lyncean* GALILEO, *who ſpeaking of his Abilities in Aſtronomy ſaith* (a) Che la felicità del ſuo ingegno non la fà biſognoſa dell' opera ſuo. *And again, ſubmitting a certain Demonſtration, which he intended to divulge, to the Judgment of this our Abbot, he writes to him in this manner:* (b) Queſto lo comunico a V. S. per lettera prima che ad alcun altro, con attenderne principalmente il parer ſuo, e doppo quello de' noſtri Amici diſcoſti, conpenſiero d' inviarne poi altre Copie ad altri Amici d' Italia, e di Francia, quando io ne venga da lei conſigliato: e qui pregandola a farci parte d' alcuna delle ſue peregrine ſpeculationi; con ſinceriſſimo affetto, &c. *And the moſt acute Mathematician* Signore Evangeliſta Terricelli, *late Profeſſour to the Grand Duke in immediate Succeſſion after* GALILEO, *maketh this Honourable and Grateful Mention of him, and his Book:* (c) Omitto magnum illum nutantis Maris motum; Prætereo etiam omnem Fluminum, Aquarumque Currentium tum menſurum, tum uſum, quarum omnis doctrina reperta primum fuit ab Abbate BENEDICTO CASTELLIO Preceptore meo. Scripſit ille Scientiam ſuam, & illam non ſolum demonſtratione, verum etiam opere confirmavit, maxima cum Principum & populorum utilitate, majore cum admiratione Phyloſophorum. Extat illius Liber, vere aureus.

(a) Nella continuatione dell Nuntio ſiderio.

(b) Lettera al P. Abbate D. B. Caſtelli D'Arcetro; li. 3. Decemb. 16 9.

(c) De Motu Aquarum. Lib. 2. Prop. 37. p. 191.

§. *I have onely two particulars more to offer the Engliſh Reader: The one concerns the Book, and it is this, That after the general Aprobation it hath had in* Italy, *I cannot but think it deſerveth the ſame Civil Entertainment with us, in regard that it cometh with no leſſe* Novelty, Facility, Verity, and Utility *to us than to thoſe whom the Authour favoured with the Original. Our Rivers and Sewers through Publique Diſtractions and Private Incroachments are in great diſorder, as thoſe Channels for inſtance which formerly were Navigable unto the very Walls of*

York

York *and* Salisbury, *&c : Our Ports are choaked and obstructed by Shelfes and Setlements : Our Fenns do in a great part lie waste and unimproved : Now all these may be (and, as I find by the Confession of some whose Practises upon the Copy of the First Book onely of our Authour hath got them both Money and Reputation, in part have been) remedied by the Ways and Means he here sets down. The truth is the Argument hath been past over with an Universal Silence; so that to this day I have not seen any thing that hath been written Demonstratively and with Mathematical Certainty concerning the same, save onely what this Learned Prelate hath delivered of his Own Invention in these Treatises: who yet hath so fully and plainly handled the Whole Doctrine, that I may affirm his Work to be every way absolute. It must be confest the Demonstration of the Second Proposition of the Second Book did not well please the Authour, and had he lived he would have supplyed that defect, but being prevented by Death, the Reader must content himself with the Mechanical Proof that he giveth you of the truth of so Excellent a Conclusion.*

§. *The other particular that I am to offer is, that out of my desire to contribute what lyeth in me to the compleating of this Piece for English Practice, I have exceeded my promise not onely in giving you the Second and following Books which were not extant at the time of tendring my Overtures, but also in that I have added a Map or Plat of all the Rivers, Lakes, Fenns, &c. mentioned thorowout the Work. And if I have not kept touch in point of Time, let it be considered that I am the Translator and not the Printer. To conclude, according to your acceptance of these my endeavours, you may expect some other Tracts of no lesse Profit and Delight.* Farewell.

T. S.

ERRATA of the *second* PART of the *first* TOME.

In PREFACE, read *Ferdinando II.* ibid. *l'Aqua.*

PAGE ~~2. LINE 26, for~~ must *read* much. ~~P.3.l.22,r.~~ and ~~let.l.25,r.~~ water, fr[illegible] 41. *r.* Tappe, *(as every where else).* ~~Page 4.l.18.r.~~ cords. Page 6.l.9. *r.* acquire, or. ~~Page 9.l.1.r.~~ irreperable. ~~P.10.l.13.r.~~ diffimboguement. *For* Page 17.*r.* P.15. ~~P.15.l.27,r.~~ in. ~~l.36,r.~~ is as. ~~l.38,r.~~ *Panaro.* ~~P.17.l.12,~~ *Giulio.* ~~l.17.r.~~ Measurers. ~~l.~~ 25, ~~r.~~ measured it, *r.* necessarily. ~~P.23.l.19.~~ *r.* for help. *for* Page 31.*r.* P.32. P. 24 l. 14, *r.* to. l. 17, *r.* namly, of the. l. 23, *r.* easie. P. 25. l. 38. *r.* Cock. p. 29. l. 7. *r.* lasted, p. 31. l. 32. *r.* Soc. p. 41. l. 20. *r.* to the line. p. 48. l. 19. *r.* us the *. id. *Figure false* p. 52 l. 30, and 31. *for* Theorem *r.* Propositon. p. 53. l. 29. *r.* again. p. 57. l. 19, *r.* same if l. 44. *r.* bodily. p. 58. l. 9, *r.* gathering. l. 40. *omit*; p. 60. l. 2. *omit*, if. p. 65. l. 1. *r.* tid *dele*; p. 66. l. 35. *r.* Stoppage of. p. 68. l. 12, *for* Lords the *r.* Lords. l. *ult. for* the *r.* it. p. 69. l. 14. *r.* to one. *id.* carried *dele* to. p. 71. l. 20, *r.* and that. l. 25, *r.* Braces; it. l 29. *r.* Braces. l. 44. *r.* the *Brent.* p. 72. l. 23. *r. Serene Highnesse.* p. 73. l. 24, *r.* deliberation: l. 26, *for* summe *r.* Moddel. l. 40. *r.* Months. p. 79. l. 18. *r.* that into. p. 82. l. 22. *dele*; p 85. l. 9, 10. *dele* a free drame. p. 88. l. 5. *r.* Palmes. p. 89. l. 8. *r.* Princes. p. 92. l. 3. *r.* Di courses. p. 93. l. 31. *r.* Tautologie. p. 94. l. 9. *r.* miracle; p. 97. l. 13 *r.* weighty. p. 101 l. 21. *r.* Marrara. p. 107. l. 28, *r.* Patrimony. l. 40, *r.* above. p. 111. l. 16. *r.* said. *For* p. 432 *r.* p. 114. p. 114. l. 35. *r.* of 200. l. 41. *r.* closed. p. 115. l. 29. *r.* constant;.

OF THE MENSURATION OF Running Waters.

LIB. I.

WHat, and of how great moment the conſideration of *Motion* is in natural things, is ſo manifeſt, that the Prince of *Peripateticks* pronounced that in his Schools now much uſed Sentence: *Ignorato motu, ignoratur natura.* Thence it is that true Philoſophers have ſo travailed in the contemplation of the Celeſtial motions, and in the ſpeculation of the motions of Animals, that they have arrived to a wonderful height and ſublimity of underſtanding. Under the ſame Science of *Motion* is comprehended all that which is written by Mechanitians concerning Engines moving of themſelves, *Machins* moving by the force of Air, and thoſe which ſerve to move weights and immenſe magnitudes with ſmall force. There appertaineth to the Science of *Motion* all that which hath been written of the alteration not onely of Bodies, but of our Minds alſo; and in ſum, this ample matter of *Motion* is ſo extended and dilated, that there are few things which fall under mans notice, which are not conjoyned with *Motion*, or at leaſt depending thereupon, or to the knowledge thereof directed; and of almoſt every of them, there hath been written and compoſed by ſublime wits, learned Treatiſes and Inſtructions.

And becauſe that in the years paſt I had occaſion by Order of our Lord Pope *Urban* 8. to apply my thoughts to the motion of the Waters of Rivers, (a matter difficult, moſt important, and little handled by others) having concerning the ſame obſerved ſome particulars not well obſerved, or conſidered till now, but of great moment both in publick and private affairs; I have thought good to publiſh them, to the end that ingenious ſpirits might have occaſion to diſcuſſe more exactly then hitherto hath been done, ſo neceſſary and profitable a matter, and to ſupply alſo my defects in this ſhort and difficult Tractate. Difficult I ſay, for the truth is, theſe knowledges, though of things next our ſenſes, are ſometimes more abſtruce and hidden, then the knowledge of things more remote; and much better, and with greater exquiſitneſs are known the motions of the Planets, and Periods of the Stars, than thoſe of Rivers and Seas: As that ſingular light of Philoſophie of our times, and my Maſter *Signore Galileo Galilei* wiſely obſerveth in his Book concerning the Solar ſpots. And to proceed with a due order in Sciences, I will take ſome ſuppoſitions and cognitions ſufficiently clear; from which I will afterwards proceed to the deducing of the principal concluſions. But to the end that what I have written at the end of this diſcourſe in a demonſtrative and Geometrical method, may alſo be underſtood of thoſe which never have applyed their thoughts to the ſtudy of Geometry; I have endeavoured to explain my conceit by an example, and with the conſideration of the natural things themſelves, much after the ſame order in which I began to doubt in this matter; and have placed this particular Treatiſe here in the beginning, adverting nevertheleſs, that he who deſires more full and abſolute ſolidity of Reaſons, may overpaſs this prefatory diſcourſe, and onely conſider what is treated of in the demonſtrations placed towards the end, and return afterwards to the conſideration of the things collected in the *Corollaries* and Appendices; which demonſtrations notwithſtanding, may be pretermitted by him that hath not ſeen at leaſt the firſt ſix Books of the Elements of Euclid; ſo that he diligently obſerveth that which followeth.

I ſay therefore, that having in times paſt, on divers occaſions heard ſpeak of the meaſures of the waters of Rivers, and Fountains, ſaying, ſuch a River is two or three thouſand feet of water; ſuch a ſpring-water is twenty, thirty, or forty inches, *&c.* Although in ſuch manner I have found all to treat thereof in word and writing, without variety, and as we are wont to ſay, *conſtanti ſermone*, yea even Artiſts and Ingeneers, as if it were a thing that admitted not of any doubt, yet howſoever I remained ſtill infolded in ſuch an obſcurity, that I well knew I underſtood

derſtood nothing at all, of that which others pretended full and clearly to underſtand. And my doubt aroſe from my frequent obſervation of many Trenches and Channels, which carry water to turn Mills, in which Trenches, and Channels, the water being meaſured, was found pretty deep; but if afterwards the ſame water was meaſured in the fall it made to turn the Wheel of the Mill, it was much leſſe, not amounting often to the tenth part, nor ſometimes to the twentieth, inſomuch, that the ſame running water came to be one while more, another while leſs in meaſure, in divers parts of its Channel; and for that reaſon this vulgar manner of meaſuring running Waters, as indeterminate and uncertain, was by me juſtly ſuſpected, the meaſure being to be determinate, and the ſame. And here I freely confeſſe that I had ſingular help to reſolve this difficulty from the excellent & accurate way of diſcourſing, as in allother matters, ſo alſo in this, of the Right Honourable and Truly Noble Signior *Ciampoli*, Secretary of the Popes ſecret affairs. Who moreover, not ſparing for the coſts of the ſame, generouſly gave me occaſion a few years paſt to try by exact experiments that which paſt concerning this particular. And to explain all more clearly with an example; we ſuppoſe a Veſſel filled with Water, as for inſtance a Butt, which is kept full, though ſtill water runneth out, and the Water run out by two Taps equal of bigneſſe, one put in the bottom of the Veſſel, and the other in the upper part; it is manifeſt that in the time wherein from the upper part ſhall iſſue a determinate meaſure of water, from the inferiour part there ſhall iſſue four, five, and many more of the ſame meaſures, according to the difference of the height of the Taps, and the diſtance of the upper Tap from the Superficies and level of the water of the Veſſel: and all this will alwayes follow, though, as hath been ſaid, the Taps be equal, and the water in diſcharging keep the ſaid Taps alwayes full. Where firſt we note, that, although the meaſure of the Taps be equal, nevertheleſſe there iſſueth from them in equal times unequal quantities of water, And if we ſhould more attentively conſider this buſineſſe, we ſhould find, that the water by the lower Tap, runneth and paſſeth with much greater velocity, then it doth by the upper, whatever is the reaſon. If therefore we would have ſuch a quantity of Water diſcharge from the upper tap, as would diſcharge from the neather in the ſame time, it is plain, that either the upper Tap muſt be multiplyed in ſuch ſort, that ſo many more Taps in number be placed above than below, as the neather tap ſhall be more ſwift than the upper, or the upper Tap made ſo much bigger than the nether, by how much that beneath ſhall be more ſwift than that above; and ſo then in equal times, the ſame quantity of Water ſhall diſcharge from the upper, as doth fromth e neather part.

I will declare my ſelf by another example. If we ſhould imagine, that two cords or lines of equal thickneſs, be drawn through two holes of equal bore; but ſo that the firſt paſs with quadruple velocity to the ſecond: It is manifeſt, that if in a determinate time, we ſhall by the firſt bore have drawn four Ells of the line, in the ſame time, by the ſecond hole we ſhall have drawn but one Ell of cord onely; and if by the firſt there paſſe twelve Ells, then through the ſecond there ſhall paſſe onely three Ells; and in ſhort the quantity of cord ſhall have the ſame proportion to the cord, that the velocity hath to the velocity. And therefore we deſiring to compenſate the tardity of the ſecond cord, and maintaining the ſame tardity to draw through the ſecond hole as much cord as through the firſt, it will be neceſſary to draw through the ſecond bore four ends of cord; ſo that the thickneſs of all the cords by the ſecond hole, have the ſame proportion to the thickneſs of the cord which paſſeth onely by the firſt, as the velocity of the cord by the firſt hole hath reciprocally to the velocity of the ~~cord~~s by the ſecond hole. And thus its clear, that when there is drawn through two holes equal quantity of cords in equal time, but with unequal velocity, it will be neceſſary, that the thickneſs of all the four cords ſhall have the ſame reciprocal proportion to the thickneſs of the ſwifter cord, that the velocity of the ſwifter cord hath to the velocity of the ſlower. The which is verified likewiſe in the fluid Element of Water.

And to the end that this principal fundamental be well underſtood, I will alſo note a certain obſervation made my me in the Art of Wyer-drawing, or ſpinning Gold, Silver, Braſs, and Iron, and it is this; That ſuch Artificers deſiring more and more to diſgroſſe and ſubtillize the ſaid Metals, having wound about a Rocket or Barrel, the thread of the Metal, they place the Rocket in a frame upon a ſtedfaſt Axis, in ſuch ſort that the Rocket may turn about in it ſelf; then making one end of the thread to paſſe by force through a Plate of Steel pierced with divers holes, greater and leſſer, as need requireth, faſtning the ſame end of the thread to another Rocket, they wind up the thread, which paſſing through a bore leſs than the thickneſſe of the thread, is of force conſtrained to diſgroſſe and ſubtillize. Now that which is intenſly to be obſerved in this buſineſs, is this, That the parts of the thread before the hole, are of ſuch a thickneſſe, but the parts of the ſame thread after it is paſſed the hole, are of a leſſer thickneſſe; and yet nevertheleſſe the maſſe and weight of the thread which is drawn forth, is ever equal to the maſſe and weight of the thread which is winded up. But if we ſhould well conſider the matter, we ſhould finde, that the thicker the thread before the hole is, than the thread paſſed the hole, the greater reciprocally is the

velocity

velocity of the parts of the thread paſſed the hole, than the velocity of the parts before the hole: Inſomuch that if *verbi gratia* the thickneſſe of the thread before the hole, were double to the thickneſſe after the hole, in ſuch caſe the velocity of the parts of the thread paſſed the hole, ſhould be double to the velocity of the parts of the thread before the hole; and thus the thickneſſe compenſates the velocity, and the velocity compenſates the thickneſſe. So that the ſame occurreth in the ſolid Metals of Gold, Silver, Braſs, Iron, &c. that eveneth alſo in the fluid Element of Water, and other liquids, namely, That the velocity beareth the ſame proportion to the velocity, that the thickneſſe of the Metal, or Water, hath to the thickneſſe.

And therefore granting this diſcourſe, we may ſay, that as often as two Taps with different velocity diſcharge equal quantities of Water in equal times, it will be neceſſary that the Tap leſſe ſwift be ſo much greater, and larger, than the Tap more ſwift, by how much the ſwifter ſuperates in velocity the ſlower; and to pronounce the Propoſition in more proper terms, we ſay; That if two Taps of unequal velocity, diſcharge in equal times equal quantities of Water, the greatneſſe of the firſt ſhall be to the greatneſſe of the ſecond, in reciprocal proportion, as the velocity of the ſecond to the velocity of the firſt. As for example, if the firſt Tap ſhall be ten times ſwifter than the ſecond Tap, it will be neceſſary, that the ſecond be ten times bigger and larger than the firſt; and in ſuch caſe the Taps ſhall diſcharge equall quantities of water in equal times; and this is the principal and moſt important point, which ought to be kept alwayes in minde, for that on it well underſtood depend many things profitable, and worthy of our knowledge.

Now applying all that hath been ſaid neerer to our purpoſe, I conſider, that it being moſt true, that in divers parts of the ſame River or Current of running water, there doth always paſſe equal quantity of Water in equal time (which thing is alſo demonſtrated in our firſt Propoſition) and it being alſo true, that in divers parts the ſame River may have various and different velocity; it follows of neceſſary conſequence, that where the River hath leſſe velocity, it ſhall be of greater meaſure, and in thoſe parts, in which it hath greater velocity, it ſhall be of leſſe meaſure; and in ſum, the velocity of ſeveral parts of the ſaid River, ſhall have eternally reciprocall and like proportion with their meaſures. This principle and fundamental well eſtabliſhed, that the ſame Current of Water changeth meaſure, according to its varying of velocity; that is, leſſening the meaſure, when the velocity encreaſeth, and encreaſing the meaſure, when the velocity decreaſeth; I paſſe to the conſideration of many par-

particular accidents in this admirable matter, and all depending on this ſole Propoſition, the ſenſe of which I have oft repeated, that it might be well underſtood.

COROLLARIE I.

AND firſt, we hence conclude, that the ſame Streams of a Torrent, namely, thoſe ſtreams which carry equal quantity of Water in equal times, make not the ſame depths or meaſures in the River, in which they enter, unleſſe when in the entrance into the River they ~~acquired~~ acquired, or to ſay better, keep the ſame velocity; becauſe if the velocicities acquired in the River ſhall be different, alſo the meaſures ſhall be diverſe; and conſequently the depths, as is demonſtrated.

COROLLARIE II.

AND becauſe ſucceſſively, as the River is more and more full, it is conſtituted ordinarily in greater & greater velocity: hence it is that the ſame ſtreams of the Torrent, that enter into the River, make leſſe and leſſe depths, as the River grows more and more full; ſince that alſo the Waters of the Torrent being entered into the River, go acquiring greater and greater velocities, and therefore diminiſh in meaſure and height.

COROLLARIE III.

WE obſerve alſo, that while the main River is ſhallow, if there fall but a gentle rain, it ſuddenly much increaſeth and riſeth; but when the River is already ſwelled, though there fall again another new violent ſhower, yet it increaſeth not at the ſame rate as before, proportionably to the rain which fell: which thing we may affirm particularly to depend on this, that in the firſt caſe, while the River is low, it is found alſo very ſlow, and therefore the little water which entereth into it, paſſeth and runs with little velocity, and conſequently occupieth a great meaſure: But when the River is once augmented, by new water being alſo made more ſwift, it cauſeth the great Flood of water which falleth, to bear a leſſe meaſure, and not to make ſuch a depth.

COROLLARIE IV.

FRom the things demonſtrated is manifeſt alſo, that whilſt a Torrent entereth into a River, at the time of Ebbe, then the Torrent moveth with ſuch a certain velocity, what ever it be,

paſſing

passing by its extreamest parts, wherewith it communicateth with the River; in which parts, the Torrent being measured, shall have such a certain measure: but the River swelling and rising, also those parts of the Torrent augment in greatnesse and measure, though the Torrent, in that instant, dis-imbogue no more water than it did before: so that the River being swelled, we are to consider two mouths of the same Torrent, one lesse before the rising, the other greater after the rising, which mouths discharge equal quantities of water in equal times; therefore the velocity by the lesser mouth shall be greater than the velocity by the greater mouth; and thus the Torrent shall be retarded from its ordinary course.

COROLLARIE V.

FRom which operation of Nature proceedeth another effect worthy of consideration; and it is, that the course of the water retarding, as hath been said in those ultimate parts of the Torrent, if it shall happen that the Torrent grow torbid and muddy, and its streame be retarded in such a degree, that it is not able to carry away those minute grains of Earth, which compose the muddinesse; in this case the Torrent shall clear away the mud, and carry away the Sand at the bottome of its own Chanel, in the extream parts of its mouth, which raised and voided Sand, shall again afterwards be carried away, when the River abating, the Torrent shall return to move with its primitive velocity.

COROLLARIE VI.

WHilst it is demonstrated, that the same water hath different measures in its Chanel or course, according as it varieth in velocity; so that the measure of the water is alwayes greater, where the velocity is lesser; and on the contrary, the measure lesser, where the velocity is greater: from hence we may most elegantly render the reason of the usual Proverb, *Take heed of the still waters*: For that if we consider the self same water of a River in those parts, wherein it is less swift, and thence called *still* or *smooth* water, it shall be, of necessity, of greater measure than in those parts, in which it is more swift, and therefore ordinarily shall be also more deep and dangerous for passengers; whence it is well said, *Take heed of the still Waters*; and this saying hath been since applied to things moral.

COROLLARIE VII.

LIkewiſe, from the things demonſtrated may be concluded, that the windes, which ſtop a River, and blowing againſt the Current, retard its courſe and ordinary velocity ſhall neceſſarily amplifie the meaſure of the ſame River, and conſequently ſhall be, in great part, cauſes; or we may ſay, potent con-cauſes of making the extraordinary inundations which Rivers uſe to make. And its moſt certain, that as often as a ſtrong and continual wind ſhall blow againſt the Current of a River, and ſhall reduce the water of the River to ſuch tardity of motion, that in the time wherein before it run five miles, it now moveth but one, ſuch a River will increaſe to five times the meaſure, though there ſhould not be added any other quantity of water; which thing indeed hath in it ſomething of ſtrange, but it is moſt certain, for that look what proportion the waters velocity before the winde, hath to the velocity after the winde, and ſuch reciprocally is the meaſure of the ſame water after the winde, to the meaſure before the winde; and becauſe it hath been ſuppoſed in our caſe that the velocity is diminiſhed to a fifth part, therefore the meaſure ſhall be increaſed five times more than that, which it was before.

COROLLARIE VIII.

WE have alſo probable the cauſe of the inundations of *Tyber*, which befel at *Rome*, in the time of *Alexander* the Sixth, & of *Clement* the Seventh; which innundations came in a ſerene time, and without great thaws of the Snows; which therefore much puzzled the wits of thoſe times. But we may with much probability affirm, That the River roſe to ſuch a height and excreſcence, by the retardation of the Waters dependant on the boiſtrous and conſtant Winds, that blew in thoſe times, as is noted in the memorials.

COROLLARIE. IX.

IT being moſt manifeſt, that by the great abundance of Water the Torrents may increaſe, and of themſelves alone exorbitantly ſwell the River; and having demonſtrated that alſo without new Water, but onely by the notable retardment the River riſeth and increaſeth in meaſure, in proportion as the velocity decreaſeth: hence it is apparent, that each of theſe cauſes being able of it ſelf, and ſeparate from the other to ſwell the River; when it ſhall happen that both theſe two cauſes conſpire the augmentation of the

the River, in such a case there must follow very great and irreparable innundations.

COROLLARIE X.

FRom what hath been demonstrated, we may with facility resolve the doubt which hath troubled, and still poseth the most diligent, but incautelous observers of Rivers, who measuring the Streams and Torrents which fall into another River; as those for instance, which enter into the *Po*, or those which fall into *Tiber*; and having summed the total of these measures, and conferring the measures of the Rivers and Brooks, which fall into *Tiber*, with the measure of *Tiber*, and the measures of those which disimbogue into *Po*, with the measure of *Po*, they find them not equal, as, it seems to them, they ought to be, and this is because they have not well noted the most important point of the variation of velocity, and how that it is the most potent cause of wonderfully altering the measures of running Waters; but, we most facilly resolving the doubt, may say that these Waters diminish the measure, being once entered the principal Channel, because they increase in velocity.

COROLLARIE XI.

THrough the ignorance of the force of the velocity of the Water, in altering its measure, & augmenting it when the velocity diminisheth; and diminishing it when the velocity augmenteth: The Architect *Giovanni Fontana*, endeavoured to measure, and and to cause to be measured by his Nephew, all the Brooks and Rivers which discharged their Waters into *Tiber*, at the time of the Innundation; which happened at *Rome* in the year 1598, and published a small Treatise thereof, wherein he summeth up the measures of the extraordinary Water which fell into *Tiber*, and made account that it was about five hundred Ells more than ordinary; and in the end of that Treatise concludeth, that to remove the Innundation wholly from *Rome*, it would be necessary to make two other Channels, equal to that at present; and that lesse would not suffice; and finding afterwards that the whole Stream passed under the Bridge *Quattro-Capi*, (the Arch whereof is of a far less measure then five hundred Ells) concludeth, that under the said Bridge past a hundred fifty one Ells of Water compressed, (I have set down the precise term of compresst Water, written by *Fontana*) wherein I finde many errors.

The first of which is to think that the measures of these Waters compressed in the Channels of those Brooks and Rivers,

ſhould maintain themſelves the ſame in *Tiber*, which by his leave, is moſt falſe, when ever thoſe waters reduced into *Tiber*, retain not the ſame velocity which they had in the place in which *Fontana* and his Nephew meaſured them: And all this is manifeſt from the things which we have above explained; for, if the Waters reduced into *Tiber* increaſe in velocity, they decreaſe in meaſure; and if they decreaſe in velocity, they increaſe in meaſure.

Secondly, I conſider that the meaſures of thoſe Brooks and Rivers, which enter into *Tiber* at the time of Innundation, are not between themſelves really the ſame, when their velocities are not equal, though they have the ſame names of Ells and Feet; for that its poſſible that a diſimboguement of ten Ells requadrated (to ſpeak in the phraſe of *Fontana*) of one of thoſe Brooks, might diſcharge into *Tiber* at the time of Innundation, four, ten, and twenty times leſs Water, than another mouth equal to the firſt in greatneſs, as would occur when the firſt mouth were four, ten, or twenty times leſs ſwift than the ſecond. Whereupon, whilſt *Fontana* ſummes up the Ells and Feet of the meaſures of thoſe Brooks and Rivers into a total aggregate, he commits the ſame error with him, which would add into one ſumme diverſe moneys of diverſe values, and diverſe places, but that had the ſame name; as if one ſhould ſay ten Crowns of *Roman* money, four Crowns of Gold, thirteen Crowns of *Florence*, five Crowns of *Venice*, and eight Crowns of *Mantua*, ſhould make the ſame ſumme with forty Crowns of Gold, or forty Crowns of *Mantua*.

Thirdly, It might happen that ſome River or Current in the parts nearer *Rome*, in the time of its flowing, did not ſend forth more Water than ordinary; and however, its a thing very clear, that whilſt the ſtream came from the ſuperior parts, that ſame Brook or River would be augmented in meaſure, as hath been noted in the fourth *Corollary*; in ſuch ſort, that *Fontana* might have inculcated, and noted that ſame River or Current as concurring to the Innundation, although it were therein altogether unconcerned.

Moreover, in the fourth place we muſt note, That it might ſo fall out, that ſuch a River not onely was unintereſſed in the Innundation, though augmented in meaſure, but it might I ſay happen, that it was inſtrumental to the aſſwaging the Innundation, by augmenting in the meaſure of its own Channel; which matter is ſufficiently evident; for if it be ſuppoſed that the River in the time of flood, had not had of it ſelf, and from its proper ſprings more Water than ordinary, its a thing certain, that the Water of *Tiber* riſing and increaſing; alſo that River, to level it ſelf with the Water of *Tiber*, would have retained ſome of

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its Waters in its own Chanel, without discharging them into *Tyber*, or else would have ingorged and swallowed (if I may so say) some of the water of *Tyber*; and in this case, at the time of Inundation, lesse abundance of water would have come to *Rome*, and yet nevertheless the measure of that River would have been increased.

Fifthly, *Fontana* deceiveth himself, when he concludeth, that to remove the Inundation from *Rome*, it would be necessary to make two other Chanels of Rivers, that were as large as that, which is the present one, and that less would not suffice, which, I say, is a fallacy: and to convince him easily of his errour, it sufficeth to say, that all the Streams being passed under the Bridge *Quattro-Capi*, as he himself attests, a Channel would suffice only of the capacity of the said Bridge, provided that the water there might run with the same velocity, as it did under the Bridge at the time of Inundation; and on the contrary, twenty Currents of capacity equal to the present one, would not suffice, if the water should run with twenty times less velocity, than it made at the time of the Inundation.

Sixthly, to me it seemeth a great weakness to say, that there should passe under the Bridge *Quattro-Capi*, an hundred fifty one ells of water compressed; for that I do not understand that water is like Cotton or Wool, which matters may be prest and trod, as it happeneth also to the air, which receiveth compression in such sort, that after that in some certain place a quantity of air shall be reduced to its natural constitution; and having taken up all the said place, yet nevertheless compressing the first Air with force and violence, it is reduced into far less room, and will admit four or six times as much air, as before, as is experimentally * seen in the Wind-Gun, invented in our dayes by *M. Vincenzo Vincenti* of *Urbin*, which property of the Air of admitting condensation, is also seen in the portable Fountains of the same *M. Vincenzo*: which Fountains spirt the Water on high, by force of the Air compressed, which whilst it seeks to reduce its self to its natural constitution, in the dilation causeth that violence. But the water can never, for any thing I know, crowd, or press so, as that if before the compression it held or possest a place, being in its natural constitution, I believe not, I say, that it is possible, by pressing and crowding to make it possess less room, for if it were possible to compress the Water, and make it to occupy a less place, it would thence follow, that two Vessels of equal measure, but of unequal height, should be of unequal capacity, and that should hold more water which was higher; also a Cylinder, or other Vessel more high than broad, would containe more water erected, than being laid along; for that being erect-

* And as is at large demonstrated by that most excellent and Honourable personage **Mr. *Boile*** in the industrious experiment of his Pneumatical Engine.

ed, the water put therein would be more preſſed and crowded.

And therefore, in our caſe, according to our principles we will ſay, that the water of that Stream paſseth all under the ſaid Bridge *Quattro-Capi*, for that being there moſt ſwift, it ought of conſequence to be leſs in meaſure.

And here one may ſee, into how many errours a man may run through ignorance of a true and real Principle, which once known and well underſtood, takes away all miſts of doubting, and eaſily reſolveth all difficulties.

COROLLARIE. XII.

THrough the ſame inadvertency of not regarding the variation of velocity in the ſame Current, therea re committed by Ingineers and Learned men, errours of very great moment (and I could thereof produce examples, but for good reaſons I paſs them over in ſilence) when they think, and propoſe, by deriving new Channels from great Rivers, to diminiſh the meaſure of the water in the River, and to diminiſh it proportionally, according to the meaſure of the Water which they make to paſs through the Channel, as making *v.g.* a Channel fifty foot broad, in which the derived water is to run waſte, ten foot deep, they think they have diminiſhed the meaſure of the Water in the River five hundred feet, which thing doth not indeed ſo fall out; and the reaſon is plain; for that the Chanel being derived, the reſt of the main River, diminiſheth in velocity, and therefore retains a greater meaſure than it had at firſt before the derivation of the Chanel; and moreover, if the Chanel being derived, it ſhall not conſerve the ſame velocity which it had at firſt in the main River, but ſhall diminiſh it, it will be neceſſary, that it hath a greater meaſure than it had before in the River; and therefore to atcompt aright, there ſhall not be ſo much water derived into the Channel, as ſhall diminiſh the River, according to the quantity of the water in the Channel, as is pretended.

COROLLARIE. XIII.

THis ſame conſideration giveth me occaſion to diſcover a moſt ordinary errour, obſerved by me in the buſineſſe of the waters of *Ferara*, when I was in thoſe parts, in ſervice of the moſt Reverend and Illuſtrious Monſignor *Corſini*; the ſublime wit of whom hath been a very great help to me in theſe contemplations; its very true, I have been much perplexed, whether I ſhould commit this particular to paper, or paſſe it over in ſilence, for that I have ever doubted, that the opinion ſo common and

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moreover confirmed with a moſt manifeſt experiment, may not onely make this my conjecture to be eſteemed far from true, but alſo diſcredit with the World the reſt of this my Treatiſe: Nevertheleſſe I have at laſt reſolved not to be wanting to my ſelf, and to truth in a matter of it ſelf, and for other conſequences moſt important; nor doth it ſeem to me requiſite in difficult matters, ſuch as theſe we have in hand, to reſigne our ſelves to the common opinion, ſince it would be very ſtrange if the multitude in ſuch matters ſhould hit on the truth, nor ought that to be held difficult, in which even the vulgar do know the truth and right; beſides that I hope morever to prove all in ſuch ſort, that perſons of ſolid judgment, ſhall reſt fully perſwaded, ſo that they but keep in mind the principal ground and foundation of all this Treatiſe; and though that which I will propoſe, be a particular, as I have ſaid, pertaining onely to the intereſts of *Ferara*; yet nevertheleſſe from this particular Doctrine well underſtood, good judgement may be made of other the like caſes in general.

I ſay then, for greater perſpecuity, and better underſtanding of the whole, That about thirteen miles above *Ferara*, near to *Stellata*, the main of *Po*, branching it ſelf into two parts, with one of its Arms it cometh cloſe to *Ferara*, retaining the name of the *Po* of *Ferara*; and here again it divideth it ſelf into two other branches, and that which continueth on the right hand, is called the *Po* of *Argenta*, and of *Primaro*; and that on the left the *Po* of *Volana*. But for that the bed of the *Po* of *Ferara* being heretofore augmented and raiſed, it followeth that it reſteth wholly deprived of the Water of the great *Po*, except in the time of its greater ſwelling; for in that caſe, this *Po* of *Ferara* being reſtrained with a Bank near to *Bondeno*, would come alſo in the overflowings of the main *Po*, to be free from its Waters: But the Lords of *Ferara* are wont at ſuch time as the *Po* threateneth to break out, to cut the bank; by which cutting, there diſgorgeth ſuch a Torrent of Water, that it is obſerved, that the main *Po* in the ſpace of ſome few hours abateth near a foot, and all perſons that I have ſpoken with hitherto, moved by this experiment, think that it is of great profit and benefit to keep ready this Vent, and to make uſe of it in the time of its fullneſſe. And indeed, the thing conſidered ſimply, and at the firſt appearance, it ſeemeth that none can think otherwiſe; the rather, for that many examining the matter narrowly, meaſure that body of Water which runneth by the Channel, or Bed of the *Po* of *Ferara*, and make account, that the body of the Water of the great *Po*, is diminiſhed the quantity of the body of the Water which runneth by the *Po* of *Ferara*. But if we well remember what hath been ſaid in the beginning of the Treatiſe, and how much

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the variety of the velocities of the ſaid Water importeth, and the knowledge of them is neceſſary to conclude the true quantity of the running Water, we ſhall finde it manifeſt, that the benefit of this Vent is far leſſe than it is generally thought: And mereover, we ſhall finde, if I deceive not my ſelf, that there follow from thence ſo many miſchiefs, that I could greatly incline to believe, that it were more to the purpoſe wholly to ſtop it up, than to maintain it open: yet I am not ſo wedded to my opinion, but that I am ready to change my judgement upon ſtrength of better reaſons; eſpecially of one that ſhall have firſt well underſtood the beginning of this my diſcourſe, which I frequently inculcate, becauſe its abſolutely impoſſible without this advertiſement to treat of theſe matters, and not commit very great errours.

I propoſe therefore to conſideration, that although it be true, that whilſt the water of the main *Po* is at its greateſt height, the Bank and Dam then cut of the *Po* of *Ferara*, and the ſuperior waters having a very great fall into the Channel of *Ferara*, they precipitate into the ſame with great violence and velocity, and with the ſame in the beginning, or little leſſe, they run towards the *Po* of *Volana*, and of *Argenta* on the ſea coaſts; yet after the ſpace of ſome few hours, the *Po* of *Ferara* being full, and the ſuperior Waters not finding ſo great a diclivity there, as they had at the beginning of the cutting, they fall not into the ſame with the former velocity, but with far leſſe, and thereby a great deal leſſe Water begins to iſſue from the great *Po*; and if we diligently compare the velocity at the firſt cutting, with the velocity of the Water after the cutting made, and when the *Po* of *Ferara* ſhall be full of Water, we ſhall finde perhaps that to be fifteen or twenty times greater than this, and conſequently the Water which iſſues from the great *Po*, that firſt impetuoſity being paſt, ſhall be onely the fifteenth or twentieth part of that which iſſued at the beginning; and therefore the Waters of the main *Po* will return in a ſmall time almoſt to the firſt height. And here I will pray thoſe who reſt not wholly ſatisfied with what hath been ſaid, that for the love of truth, and the common good, they would pleaſe to make diligent obſervation whether in the time of great Floods, the ſaid Bank or Dam at *Bondeno* is cut, and that in few hours the main *Po* diminiſheth, as hath been ſaid about a foot in its height; that they would obſerve I ſay, whether, a day or two being paſt, the Waters of the main *Po* return almoſt to their firſt height; for if this ſhould follow, it would be very clear, that the benefit which reſulteth from this diverſion or Vent, is not ſo great as is univerſally preſumed; I ſay, it is not ſo great as is preſumed; becauſe, though it be granted for true, that the Waters of the main *Po*, abate at the beginning of

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the Vent, yet this benefit happens to be but temporary and for a few hours: If the riſing of *Po*, and the dangers of breaking forth were of ſhort duration, as it ordinarily befalleth in the overflowings of Torrents, in ſuch a caſe the profit of the Vent would be of ſome eſteem: But becauſe the ſwellings of *Po* continue for thirty, or ſometimes for forty dayes, therefore the gain which reſults from the Vent proveth to be inconſiderable. It remaineth now to conſider the notable harms which follow the ſaid Sluice or Vent, that ſo reflection being made, and the profit and the detriment compared, one may rightly judge, and chooſe that which ſhall be moſt convenient. The firſt prejudice therefore which ariſeth from this Vent or Sluice, is; That the Channels of *Ferara*, *Primaro*, and *Volana* filling with Water, all thoſe parts from *Bondeno* to the Sea ſide are allarmed and endangered thereby. Secondly, The Waters of the *Po* of *Primaro* having free ingreſſe into the upper Valleys, they fill them to the great damage of the Fields adjacent, and obſtruct the courſe of the ordinary Trenches in the ſame Valleys; inſomuch that all the care, coſt, and labour about the draining, and freeing the upper Valleys from Water, would alſo become vain and ineffectual. Thirdly, I conſider that theſe Waters of the *Po* of *Ferara* being paſſed downwards towards the Sea, at the time that the main *Po* was in its greater excreſcences and heights, it is manifeſt by experience, that when the great *Po* diminiſheth, then theſe Waters paſſed by the *Po* of *Ferara* begin to retard in their courſe, and finally come to turn the current upwards towards *Stellata*, reſting firſt in the intermediate time, almoſt fixed and ſtanding, and therefore depoſing the muddineſſe, they fill up the Channel of the River or Current of *Ferara*. Fourthly and laſtly, There followeth from this ſame diverſion another notable damage, and it is like to that which followeth the breaches made by Rivers; near to which breaches in the lower parts, namely below the breach, there is begot in the Channel of the River, a certain ridge or ſhelf, that is, the bottom of the River is raiſed, as is ſufficiently manifeſt by experience; and thus juſt in the ſame manner cutting the Bank at *Bondeno*, there is as it were a breach made, from which followeth the riſing in the lower parts of the main *Po*, being paſt the mouth of *Panaro*; which thing, how pernitious it is, let any one judge that underſtandeth theſe matters. And therefore both for the ſmall benefit, and ſo many harms that enſue from maintaining this diverſion, I ſhould think it were more ſound advice to keep that Bank alwaies whole at *Bondeno*, or in any other convenient place, and not to permit that the Water of the Grand *Po* ſhould ever come near to *Ferara*.

Panaro

COROLLARIE XIV.

IN the Grand Rivers, which fall into the Sea, as here in *Italy* *Po*, *Adige*,* and *Arno*, which are armed with Banks against their excreſcencies, its obſerved that far from the Sea, they need Banks of a notable height; which height goeth afterwards by degrees diminiſhing, the more it approacheth to the Sea-coaſts: in ſuch ſort, that the *Po*, diſtant from the Sea about fifty or ſixty miles at *Ferara*, ſhall have Banks that be above twenty feet higher than the ordinary Water-marks; but ten or twelve miles from the Sea, the Banks are not twelve feet higher than the ſaid ordinary Water-marks, though the breadth of the River be the ſame, ſo that the excreſcence of the ſame Innundation happens to be far greater in meaſure remote from the Sea, then near; and yet it ſhould ſeem, that the ſame quantity of Water paſſing by every place, the River ſhould need to have the ſame altitude of Banks in all places: But we by our Principles and fundamentals may be able to render the reaſon of that effect, and ſay; That that exceſſe of quantity of Water, above the ordinary Water, goeth alwaies acquiring greater velocity; the nearer it approacheth the Sea, and therefore decreaſeth in meaſure, and conſequenly in height. And this perhaps might have been the cauſe in great part, why the *Tyber* in the Innundation *Anno* 1578. iſſued not forth of its Channel below *Rome* towards the Sea.

* *Arteſia.*

COROLLARIE XV.

FRom the ſame Doctrine may be rendred a moſt manifeſt reaſon why the falling Waters go leſſening in their deſcent, ſo that the ſame falling Water, meaſured at the beginning of its fall, is greater, and bigger, and afterwards by degrees leſſeneth in meaſure the more it is remote from the beginning of the fall. Which dependeth on no other, than on the acquiſition, which it ſucceſſively makes of greater velocity; it being a moſt familiar concluſion among Philoſophers, that grave bodies falling, the more they remove from the beginning of their motion, the more they acquire of ſwiftneſſe; and therefore the Water, as a grave body, falling, gradually velocitates, and therefore decreaſeth in meaſure, and leſſeneth.

COROLLARIE XVI.

AND on the contrary, the ſpirtings of a Fountain of Water, which ſpring on high, work a contrary effect; namely

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in the beginning they are ſmall, and afterwards become greater and bigge; and the reaſon is moſt manifeſt, becauſe in the beginning they are very ſwift, and afterwards gradually relent their impetuoſity, and motion; ſo that in the beginning of the excurſion that they make, they ought to be ſmall, and afterwards to grow bigger, as in the effect is ſeen.

APPENDIX. I.

INto the errour of not conſidering how much the different velocities of the ſame running water in ſeveral places of its current, are able to change the meaſure of the ſame water, and to make it greater; or leſſe, I think, if I be not deceived, that *Giulio Frontino* a noble antient Writer, may have faln in the ſecond Book which he writ, of the Aqueducts of the City of *Rome*: Whilſt finding the meaſure of the Water *Commentariis* leſſe than it was *in erogatione* 1263. *Quinaries*, he thought that ſo much difference might proceed from the negligence of the Meaſurers; and when afterwards with his own induſtry he meaſured the ſame water at the beginnings of the Aqueducts, finding it neer 10000. *Quinaries* bigger than it was *in Commentariis* he judged, that the overplus was imbeziled by Miniſters and Partakers; which in part might be ſo, for it is but too true, that the publique is almoſt alwayes defrauded; yet nevertheleſſe, I verily believe withal, that beſides the frauds of theſe Officers, the velocities of the water in the place wherein *Frontino* meaſured, it might be different from thoſe velocities, which are found in other places before meaſured by others; and therefore the meaſures of the waters might, yea ought neceſſarily to be different, it having been by us demonſtrated, that the meaſures of the ſame running water have reciprocal proportion to their velocities. Which *Frontino* not well conſidering, and finding the water *in Commentariis* 12755. *Quinaries in erogatione* 14018; and in his own meaſure *ad capita ductuum*, at the head of the fountain 22755. *Quinaries*, or thereabouts, he thought, that in all theſe places there paſt different quantities of water; namely, greater at the fountain head then that which was *in Erogatione*, and this he judged greater than that which was *in Commentariis*.

* *Commentarius* beareth many ſenſes, but in this place ſignifieth a certain Regiſter of the quantities of the Waters in the ſeveral publique Aquiducts of *Rome*; which word I find frequently uſed in the Law-books of antient Civilians: And by errogation we are to underſtand the diſtribution or delivering out of thoſe ſtores of Water.

APPENDIX II.

A Like miſtake chanced lately in the Aqueduct of *Acqua-Paola*, which Water ſhould be 2000 Inches, and ſo many effectively ought to be allowed; and it hath been given in

ſo to be by the Signors of *Bracciano* to the *Apoſtolick-Chamber*; and there was a meaſure thereof made at the beginning of the Aqueduct; which meaſure proved afterwards much leſſe and ſhort, conſidered and taken in *Rome*, and thence followed diſcontents and great diſorders, and all becauſe this property of Running-Waters, of increaſing in meaſure, where the velocity decreaſed; and of diminiſhing in meaſure, where the velocity augmented, was not lookt into.

APPENDIX III.

ALike errour, in my judgement, hath beeen committed by all thoſe learned men, which to prevent the diverſion of the *Reno* of *Bologna* into *Po* by the Channels, through which it at preſent runneth, judged, that the *Reno* being in its greater excreſcence about 2000. feet, and the *Po* being near 1000. feet broad, they judged, I ſay, that letting the *Reno* into *Po*, it would have raiſed the Water of *Po* two feet; from which riſe, they concluded afterwards moſt exorbitant diſorders, either of extraordinary Inundations, or elſe of immenſe and intolerable expences to the people in raiſing the Banks of *Po* and *Reno*, and with ſuch like weakneſſes, often vainly diſturbed the minds of the perſons concerned: But now from the things demonſtrated, it is manifeſt, That the meaſure of the *Reno* in *Reno*, would be different from the meaſure of *Reno* in *Po*; in caſe that the velocity of the *Reno* in *Po*, ſhould differ from the velocity of *Reno* in *Reno*, as is more exactly determined in the fourth Propoſition.

APPENDIX IV.

NO leſs likewiſe are thoſe Ingeneers and Artiſts deceived, that have affirmed, That letting the *Reno* into *Po*, there would be no riſe at all in the Water of *Po*: For the truth is, That letting *Reno* into *Po*, there would alwaies be a riſing; but ſometimes greater, ſometimes leſſe, as the *Po* ſhall have a ſwifter or ſlower Current; ſo that if the *Po* ſhall be conſtituted in a great velocity, the riſe will be very ſmall; and if the ſaid *Po* ſhall be ſlow in its courſe, then the riſe will be notable.

APPENDIX V.

AND here it will not be beſides the purpoſe to advertiſe, That the meaſures, partments, and diſtributions of the Waters of Fountains, cannot be made exactly, unleſs there be conſidered

sidered, besides the measure, the velocity also of the Water; which particular not being thorowly observed, is the cause of continual miscariages in such like affairs.

APPENDIX VI.

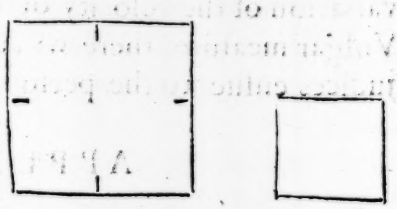
LIke consideration ought to be had with the greater diligence, for that an errour therein is more prejudicial; I say, ought to be had by those which part and divide VVaters; for the watering of fields, as is done in the Territories of *Brescia*, *Bergama*, *Cremia*, *Pavia*, *Lodigiano*, *Cremona*, and other places. For if they have not regard to the most important point of the variation of the velocity of the VVater, but onely to the bare Vulgar measure, there will alwaies very great disorders and prejudices ensue to the persons concerned.

APPENDIX VII.

IT seemeth that one may observe, that whilst the Water runneth along a Channel, Current, or Conduit, its velocity is retarded, withheld, and impeded by its touching the Bank or side of the said Channel or Current, which, as immoveable, not following the motion of the VVater, interrupteth its velocity. From which particular, being true, as I believe it to be most true, and from our considerations, we have an occasion of discovering a very nice mistake, into which those commonly fall who divide the VVaters of Fountains. VVhich division is wont to be, by what I have seen here in *Rome* performed two wayes. The first of which is with the measures of like figures, as Circles, or Squares; having cut through a Plate of metal several Circles or Squares, one of half an inch, another of one inch, another of two, of three, of four, &c. with which they afterwards adjust the Cocks to dispence the VVaters. The other manner of dividing the VVaters of Fountains, is with rectangle paralellograms, of the same height, but of different Bases, in such sort likewise, that one paralellogram be of half an inch, another of one, two, three, &c. In which manner of measuring and dividing the Water, it should seem that the Cocks being placed in one and the same plain, equidistant from the level, or superior superficies of the water of the Well; and the said measures being most exactly made, the VVater ought consequently also to be equally divided, and parted according to the proportion of the measures. But if we well consider every particular, we shall finde, that the Cocks, as they successively are greater, discharge alwaies more VVater than the just quantity, in comparison of

the leſſer; that is, to ſpeak more properly, The VVater which paſſeth through the greater Cock, hath alwaies a greater proportion to that which paſſeth through the leſſer, than the greater Cock hath to the leſſer. All which I will declare by an example.

Let there be ſuppoſed for more plainneſs two Squares; (the ſame may be underſtood of Circles, and other like Figures) The firſt Square is, as we will ſuppoſe, quadruple to the other, and theſe Squares are the mouths of two Cocks; one of four inches, the other of one: Now its manifeſt by what hath been ſaid, that the VVater which paſſeth by the leſs Cock, findeth its velocity impeded in the circumference of the Cock; which impediment is meaſured by the ſaid circumference. Now it is to be conſidered, that if we would have the Water which paſſeth through the greater Cock, to be onely quadruple to that which paſſeth through the leſſe, in equal ſpaces of time, it would be neceſſary, that not onely the capacity and the meaſure of the greater Cock be quadruple to the leſſer Cock, but that alſo the impediment be quadrupled. Now in our caſe it is true, That the belly and mouth of the Cock is quadrupled, and yet the impediment is not quadrupled, but is onely doubled; ſeeing that the circumference of the greater Square, is onely double to the circumference of the leſſer Square; for the greater circumference containeth eight of thoſe parts, of which the leſſer containeth but four; as is manifeſt by the deſcribed Figure; and for that cauſe there ſhall paſs by the greater Cock, above four times as much VVater, as ſhall paſs by the leſſer Cock.



The like errour occurreth alſo in the other manner of meaſuring the VVater of a Fountain, as may eaſily be collected from what hath been ſaid and obſerved above.

APPENDIX VIII.

THe ſame contemplation diſcovereth the errour of thoſe Architects, who being to erect a Bridge of ſundry Arches over a River, conſider the ordinary breadth of the River; which being e. g. fourty fathom, and the Bridge being to conſiſt of four Arches, it ſufficeth them, that the breadth of all the four Arches taken together, be fourty fathom; not conſidering that in the ordinary Channel of the River, the Water hath onely two impediments which retard its velocity; namely, the touching and gliding along the two ſides or ſhores of the River; but the

the ſame water in paſſing under the Bridge, in our caſe meeteth with eight of the ſame impediments, bearing, and thruſting upon two ſides of each Arch (to omit the impediment of the bottom, for that it is the ſame in the River, and under the Bridge) from which inadvertency ſometimes follow very great diſorders, as quotidian practice ſhews us.

APPENDIX IX.

IT is alſo worthy to conſider the great and admirable benefit that thoſe fields receive, which are wont to drink up the Rain-water with difficulty, through the height of the water in the principal Ditches; in which caſe the careful Husbandman cutteth away the reeds and ruſhes in the Ditches, through which the waters paſs; whereupon may be preſently ſeen, ſo ſoon as the reeds and ruſhes are cut, a notable Ebb in the level of the water in the Ditches; inſomuch that ſometimes it is obſerved, that the water is abated after the ſaid cutting a third and more, of what it was before the cutting. The which effect ſeemingly might depend on this, That, before thoſe weeds took up room in the Ditch, and for that cauſe the water kept a higher level, and the ſaid Plants being afterwards cut and removed, the water came to abate, poſſeſſing the place that before was occupied by the weeds: Which opinion, though probable, and at firſt ſight ſatisfactory, is nevertheleſs inſufficient to give the total reaſon of that notable abatement which hath been ſpoken of: But it is neceſſary to have recourſe to our conſideration of the velocity in the courſe of the water, the chiefeſt and true cauſe of the variation of the meaſure of the ſame Running-Water; for, that multitudes of reeds, weeds, and plants diſperſed through the current of the Ditch, do chiefly notably to retard the courſe of the water, and therefore the meaſure of the water increaſeth; and thoſe impediments removed, the ſame water gaineth velocity, and therefore decreaſeth in meaſure, and conſequently in height.

And perhaps this point well underſtood, may be of great profit to the fields adjacent to the *Pontine* Fens, and I doubt not but if the River *Niuſa*, and the other principal Brooks of thoſe Territories were kept well cleanſed from weeds, their waters would be at a lower level, and conſequently the drains of the fields would run into them more readily; it being always to be held for undoubted, that the meaſure of the water before the cleanſing, hath the ſame proportion to the meaſure after cleanſing, that the velocity after the cleanſing hath to the velocity before the cleanſing: And becauſe thoſe weeds being cleanſed

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away, the courſe of the water notably increaſeth, it is therefore neceſſary that the ſaid water abate in meaſure, and become lower.

APPENDIX. X.

WE having above obſerved ſome errors that are committed in diſtributing the waters of Fountains, and thoſe that ſerve to water fields; it ſeemeth now fit, by way of a cloſe to this diſcourſe, to advertiſe by what means theſe diviſions may be made juſtly and without error. I therefore think that one might two ſeveral wayes exquiſitly divide the water of Fountains; The firſt would be by diligently examining, First, how much water the whole Fountain diſchargeth in a determinate time, as for inſtance: How many Barrels, or Tuns it carrieth in a ſet time; and in caſe you are afterwards to diſtribute the water, diſtribute it at the rate of ſomany Barrels or Tuns, in that ſame time; and in this caſe the participants would have their punctual ſhares: Nor could it ever happen to ſend out more water, than is reckoned to be in the principal Fountain; as befel *Giulio Frontino*, and as alſo it frequently happeneth in the Modern Aqueducts, to the publick and private detriment.

The other way of dividing the ſame waters of a Fountain, is alſo ſufficiently exact and eaſie, and may be, by having one onely ſize for the Cock or Pipe, as ſuppoſe of an inch, or of half an inch; and when the caſe requireth to diſpence two, three, and more inches, take ſo many Cocks of the ſaid meaſure, as do evacuate the water, which is to be emitted; and if we are to make uſe onely of one greater Cock, we being to place one to diſcharge for example four inches; and having the former ſole meaſure of an inch, we muſt make a Cock that is bigger, its true, than the Cock of one inch; but not ſimply in a quadruple proportion, for that it would diſcharge more than juſt ſo much water, as hath been ſaid above; but we ought to examine diligently how much water the little Cock emitteth in an hour; and then enlarge, and contract the greater Cock, ſo, that it may diſcharge four times as much water as the leſſer in the ſame time; and by this means we ſhall avoid the diſorder hinted in the ſeventh Appendix. It would be neceſſary nevertheleſs, to accommodate the Cocks of the Ciſtern, ſo that the level of the water in the Ciſtern may alwayes reſt at one determinate mark above the Cock; otherwiſe the Cocks will emit ſometimes greater, and ſometimes leſſe abundance of water: And becauſe it may be that the ſame water of the Fountain may be ſometimes more abundant, ſometimes leſs; in ſuch caſe it will be neceſſary

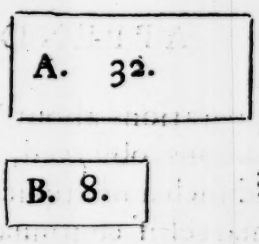
to

to adjuſt the Ciſtern ſo, that the exceſs above the ordinary water, diſcharge into the publick Fountains, that ſo the particular participants may have alwayes the ſame abundance of water.

APPENDIX XI.

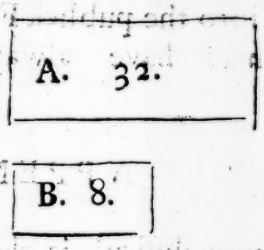
MUch more difficult is the diviſion of the waters which ſerve to water the fields, it not being poſſible to obſerve ſo commodiouſly, what quantity of water the whole Ditch ſends forth in one determinate time, as may be done in Fountains: Yet nevertheleſs, if the ſecond propoſition by us a little below demonſtrated, be well underſtood, there may be thence taken a very ſafe and juſt way to diſtribute ſuch waters. The Propoſition therefore by us demonſtrated is this: If there be two Sections, (namely two mouths of Rivers) the quantity of the water which paſſeth by the firſt, hath a proportion to that which paſſeth by the ſecond, compounded of the proportions of the firſt Section to the ſecond, and of the velocity through the firſt, to the velocity through the ſecond: As I will declare for example by help of practice, that I may be underſtood by all, in a matter ſo important. Let the two mouths of the Rivers be A, and B, and let the mouth A be in meaſure and content thirty two feet, and the mouth B, eight feet. Here you muſt take notice, that it is not alwayes true, that the Water which paſſeth by A, hath the ſame proportion to that which paſſeth by B, that the mouth A hath to the mouth B; but onely when the velocityes by each of thoſe paſſages are equal: But if the velocityes ſhall be unequal, it may be that the ſaid mouths may emit equal quantity of Water in equal times, though their meaſure be unequal; and it may be alſo, that the bigger doth diſcharge a greater quantity of Water: And laſtly, it may be, that the leſs mouth diſchargeth more Water than the greater; and all this is manifeſt by the things noted in the beginning of this diſcourſe, and by the ſaid ſecond Propoſition. Now to examine the proportion of the Water that paſſeth by one Ditch, to that which paſſeth by another, that this being known, the ſame Waters and mouths of Ditches may be then adjuſted; we are to keep account not onely of the greatneſs of the mouths or paſſages of the Water, but of the velocity alſo; which we will do, by firſt finding two numbers that have the ſame proportion between themſelves,

by example for



31. 8. 4.

ſelves, as have the mouths; which are the numbers 32 and 8 in our example: Then this being done, let the velocity of the Water by the paſſages A and B, be examined (which may be done keeping account what ſpace a piece of Wood, or other body that ſwimmeth, is carried by the ſtream in one determinate time; as for inſtance in 50 pulſes) and then work by the golden Rule, as the velocity by A, is to the velocity by B, ſo is the number 8, to another number, which is 4. It is clear by what is demonſtrated in the ſaid ſecond Propoſition, that the quantity of water, which paſſeth by the mouth A, ſhall have the ſame proportion of that which paſſeth by the mouth B, that 8 hath to 1. Such proportion being compoſed of the proportions of 32 to 8, and of 8 to 4; namely, to the greatneſs of the mouth A, to the greatneſs of the mouth B, and of the velocity in A, to the velocity in B. This being done, we muſt then contract the mouth which diſchargeth more then its juſt quantity of water, or enlarge the other which diſchargeth leſs, as ſhal be moſt commodious in practice, which to him that hath underſtood this little that hath been delivered, will be very eaſie.

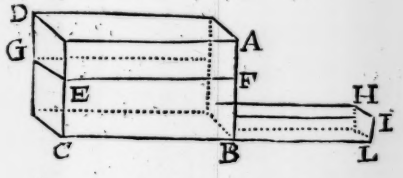


APPENDIX XII.

THeſe opperations about Water, as I have hitherto on ſundry occaſions obſerved, are involved in ſo many difficulties, and ſuch a multiplicity of moſt extravagant accidents, that it is no marvel if continually many, and very important errours be therein committed by many, and even by Ingeneers themſelves, and Learned-men; and becauſe many times they concern not onely the publique, but private intereſts: Hence it is, that it not onely belongeth to Artiſts to treat thereof, but very oft even the vulgar themſelves pretend to give their judgement therein: And I have been troubled many times with a neceſſity of treating, not onely with thoſe, which either by practice, or particular ſtudy, underſtood ſomewhat in theſe matters; but alſo with people wholly void of thoſe notions, which are neceſſary for one that would on good grounds diſcourſe about this particular; and thus many times have met with more difficulty in the thick skulls of men, than in precipitous Torrents, and vaſt Fennes. And in particular, I had occaſion ſome years paſt to go ſee the Cave or Emiſſary of the Lake of *Perugia*, made many years agon by *Braccio Fortobraccio*, but for that it was with great ruines by Time decayed, and rendred unuſeful, it was repaired with induſtry

duſtry truly heroicall and admirable, by Monſignor *Maffei Barberino*, then Prefect for the Wayes, and now Pope. And being neceſſitated, that I might be able to walk in the Cave, and for other cauſes, I let down the Sluices of the ſaid Cave, at the mouth of the Lake: No ſooner were they ſtopt, but a great many of the people of the Towns and Villages coaſting upon the *Lake* flocking thither, began to make grievous complaints, that if thoſe Sluices were kept ſhut, not onely the Lake would want its due Vent, but alſo the parts adjacent to the Lake would be over flown to their very great detriment. And becauſe at firſt appearance their motion ſeemed very reaſonable, I found my ſelf hard put to it, ſeeing no way to perſwade ſuch a multitude, that the prejudice which they pretended I ſhould do them by keeping the Sluices ſhut for two dayes, was abſolutely inſenſible; and that by keeping them open, the Lake did not ebb in the ſame time ſo much as the thickneſs of a ſheet of Paper: And therefore I was neceſſitated to make uſe of the authority I had, and ſo followed my buſineſs as cauſe required, without any regard to that Rabble tumultuouſly aſſembled. Now when I am not working with Mattock or Spade, but with the Pen and Diſcourſe, I intend to demonſtrate clearly to thoſe that are capable of reaſon, and that have well underſtood the ground of this my Treatiſe, that the fear was altogether vain which thoſe people conceited. And therefore I ſay, that the Emiſſary or Sluice of the Lake of *Perugia*, ſtanding in the ſame mannner as at preſent, and the water paſſing thorow it with the ſame velocity as now; to examine how much the Lake may abate in two days ſpace, we ought to conſider, what proportion the ſuperficies of the whole Lake hath to the meaſure of the Section of the Emiſſary, and afterwards to infer, that the velocity of the water by the Emiſſary or Sluice, ſhall have the ſame proportion to the abatement of the Lake, and to prove thorowly and clearly this diſcourſe, I intend to demonſtrate the following Propoſition.

Suppoſe a Veſſel of any bigneſſe, and that it hath an Emiſſary or Cock, by which it diſchargeth its water. And look what proportion the ſuperficies of the veſſel hath to the meaſure of the ſection of the cock, ſuch proportion ſhall the velocity of the Water in the Cock have to the abatement of the Lake. Let the Veſſel be A B C D, H I L B, through which the Water runneth, the ſuperficies of the Water in the Veſſel A D, and the ſection of the Cock H L: and let the Water in the Veſſel be ſuppoſed to have falne in one determinate time from A to F.



I ſay that the proportion of the ſuperficies of the Veſſel A D is in proportion to the meaſure of the ſection of the Emiſſary H L, as the velocity of the Emiſſary or Cock to the line A F; which is manifeſt, for that the Water in the Veſſel moving by the line A F; as far as F, and the whole maſs of Water A G diſcharging it ſelf, and in the ſame time the ſame quantity of Water being diſcharged by the ſection of the Emiſſary H L; it is neceſſary by what I have demonſtrated in the third Propoſition, and alſo explained in the beginning of this Treatiſe, that the velocity by the Emiſſary or Cock be in proportion to the velocity of the abatement, as the ſuperficies of the Veſſel to the meaſure of the ſection of the Emiſſary, which was to be demonſtrated.

That which hath b.en demonſtrated in the Veſſel, falls out exactly alſo in our Lake of *Perugia*, and its Emiſsary; and becauſe the immenſity of the ſuperficies of the Lake is in proportion to the ſuperficies of the Emiſsary or Sluice, as many millions to one, as may be eaſily calculated; it is manifeſt, that ſuch abatement ſhall be imperceptible, and almoſt nothing, in two dayes ſpace, nay in four or ſix: and all this will be true, when we ſuppoſe that for that time there entreth no other Water into the Lake from Ditches or Rivolets, which falling into the Lake would render ſuch abatement yet leſs.

Now we ſee, that it's neceſsary to examine ſuch abatements and riſings, with excellent reaſons, or at leaſt, with accurate experiments, before we reſolve and conclude any thing; and how farre the vulgar are diſtant from a right judgement in ſuch matters.

APPENDIX XIII.

FOR greater confirmation of all this which I have ſaid, I will inſtance in another like caſe, which alſo I met with heretofore, wherein, for that the buſineſs was not rightly underſtood, many diſorders, vaſt expences, and conſiderable miſchiefs have followed. There was heretofore an Emiſsary or Sluice made to drain the Waters, which from Rains, Springs, and Rivolets fall into a Lake; to the end, the ſhores adjoyning on the Lake, ſhould be free from the overflowing of the Waters; but becauſe perhaps the enterprize was not well managed and carried on, it fell out, that the Fields adjacent to the ſaid Chanel could not drain, but continued under water; to which diſorders a preſent remedy hath been uſed, namely, in a time convenient to ſtop up the Sluice, by meanes of certain Floodgates kept on purpoſe for that end; and thus abating the Level of the Water

in

in the Emiſſary, in the ſpace of three or four dayes, the Fields have been haply drained. But on the other part, the proprietors bordering on the Lake oppoſed this, grievouſly complaining, that whilſt the Floodgates are ſhut, and the courſe of the Water of the Sluice hindered, the Lake overflowes the Lands adjacent, by meanes of the Rivers that fell into it, to their very great damage; and ſo continuing their ſuits, they got more of vexation than ſatisfaction. Now, being asked my opinion herein, I judged it requiſite (ſince the point in controverſie was about the riſing and falling of the Lake) that the ſaid abatement, when the Floodgates are open, and increaſe when they are ſhut ſhould be exactly meaſured, and told them, that it might be eaſily done at a time when no extraordinary Waters fell into the Lake, neither of Rain, or otherwiſe; and the Lake was undiſturbed by winds that might drive the Water to any ſide, by planting neer to an Iſlet, which is about the middle of the Lake, a thick poſt, on which ſhould be made the marks of the Lakes riſing and falling for two or three dayes. I would not, at that time, pawn, or reſolutely declare, my judgment, in regard I might be, by divers accidents miſſed. But this I told them, that (by what I have demonſtrated, and particularly that which I have ſaid above touching the Lake of *Perugia*) I inclined greatly to think, that theſe riſings and fallings would prove imperceptible, and inconſiderable; and therefore, that in caſe experience ſhould make good my reaſon, it would be to no purpoſe for them to continue diſputing and wrangling, which cauſeth, (according to the Proverb) *A great deal of cry*, but produceth not much *Wool*.

Laſtly, it importing very much to know what a Rain continued for many dayes can do in raiſing theſe Lakes, I will here inſert the Copy of a Letter, which I writ formerly to *Signior Galilæo Galilæi*, chief Philoſopher to the Grand Duke of *Tuſcany*, wherein I have delivered one of my conceits in this buſineſſe, and it may be, by this Letter, I may, more ſtrongly, confirm what I have ſaid above.

The Copy of a Letter to Signore GALILÆO GALILÆI, *Chief Philosopher to the most Serene Great Duke of* TUSCANY.

Worthy and most Excellent SIR,

IN satisfaction of my promise, in my former Letters of representing unto you some of my Considerations made upon the Lake *Thrasimeno*, I say, That in times past, being in *Perugia*, where we held our General Convention, having understood that the Lake *Thrasimeno*, by the great drought of many Moneths was much abated, It came into my head, to go privately and see this novelty, both for my particular satisfaction, as also that I might be able to relate the whole to my Patrons, upon the certitude of my own sight of the place. And so being come to the Emissary of the Lake, I found that the Level of the Lakes surface was ebbed about five Roman Palmes of its wonted watermark, insomuch that it was lower than the transome of the mouth of the Emissary, by the length of _____ this described line, and therefore no Water issued out of the Lake, to the great prejudice of all the places and villages circumjacent, in regard that the Water which used to run from the said Lake turned 22 Mills, which not going, necessitated the inhabitants of those parts to go a dayes journey and more, to grinde upon the *Tiber*. Being returned to *Perugia*, there followed a Rain, not very great, but constant, and even, which lasted for the space of eight hours, or thereabouts; and it came into my thoughts to examine, being in *Perugia*, how much the Lake was increased and raised by this Rain, supposing (as it was probable enough) that the Rain had been universal over all the Lake; and like to that which fell in *Perugia*, and to this purpose I took a Glasse formed like a Cylinder, about a palme high, and half a palme broad; and having put in water sufficient to cover the bottome of the Glasse, I noted diligently the mark of the height of the Water in the Glasse, and afterwards exposed it to the open weather, to receive the Raine-water, which fell into it; and I let it stand for the space of an hour; and having observed that in that time the Water was risen in the Vessel the height of the following line——, I considered that if I had exposed to the same rain such other vessels equal to that, the Water would have risen in them all according to that measure: And thereupon concluded, that also in all the

the whole extent of the Lake, it was neceſſary the Water ſhould be raiſed in the ſpace of an hour the ſame meaſure. Yet here I conſidered two difficulties that might diſturb and altar ſuch an effect, or at leaſt render it inobſerveable, which afterwards well weighed, and reſolved, left me (as I will tell you anon) in the concluſion the more confirmed; that the Lake ought to be increaſed in the ſpace of eight hours, that the rain laſted eight times that meaſure. And whilſt I again expoſed the Glaſs to repeat the experiment, there came unto me an Ingeneer to talk with me touching certain affairs of our Monaſtary of *Perugia*, and diſcourſing with him, I ſhewed him the Glaſs out at my Chamber-window, expoſed in a Court-yard; and communicated to him my fancy, relating unto him all that I had done. But I ſoon perceived that this brave fellow conceited me to be but of a dull brain, for he ſmiling ſaid unto me; Sir, you deceive your ſelf: I am of opinion that the Lake will not be increaſed by this rain, ſo much as the thickneſſe of a * *Julio*. Hearing him pronounce this his opinion with freenes and confidence, I urged him to give me ſome reaſon for what he ſaid, aſſuring him, that I would change my judgement, when I ſaw the ſtrength of his Arguments: To which he anſwered, that he had been very converſant about the Lake, and was every day upon it, and was well aſſured that it was not at all increaſed. And importuning him further, that he would give me ſome reaſon for his ſo thinking, he propoſed to my conſideration the great drought paſſed, and that that ſame rain was nothing for the great parching: To which I anſwered, I believe Sir that the ſurface of the Lake, on which the rain had fallen was moiſtned, and therefore ſaw not how its drought, which was nothing at all, could have drunk up any part of the rain. For all this he perſiſting in his conceit, without yielding in the leaſt to my allegation; he granted in the end (I believe in civility to me) that my reaſon was plauſible and good, but that in practile it could not hold. At laſt to clear up all, I made one be called, and ſent him to the mouth of the Emiſſary of the Lake, with order to bring me an exact account, how he found the water of the Lake, in reſpect of the Tranſome of the Sluice. Now here, Signore *Galilæo*, I would not have you think that I had brought the matter in hand to concern me in my honour; but believe me (and there are witneſſes of the ſame ſtill living) that my meſſenger returning in the evening to *Perugia*, he brought me word, that the water of the Lake began to run through the Cave; and that it was riſen almoſt a fingers breadth above the Tranſome: Inſomuch, that adding this meaſure, to that of the lowneſs of the ſurface of the Lake, beneath the Tranſome before the rain,

* A Coyn of Pope *Julius* worth ſix pence.

it

it was manifeſt that the riſing of the Lake cauſed by the rain, was to a hair thoſe four fingers breadth that I had judged it to be. Two dayes after I had another bout with the Ingeneer, and related to him the whole buſineſs, to which he knew not what to anſwer.

Now the two difficulties which I thought of, able to impede my concluſion, were theſe following: First, I conſidered that it might be, that the Wind blowing from the ſide where the Sluice ſtood, to the Lake-ward; the mole and maſs of the Water of the Lake might be driven to the contrary ſhore; on which the Water riſing, it might be fallen at the mouth of the Emiſſary, and ſo the obſervation might be much obſcured. But this difficulty wholly vaniſhed by reaſon of the Aires great tranquility; which it kept at that time, for no Wind was ſtirring on any ſide, neither whilſt it rained, nor afterwards.

The ſecond difficulty which put the riſing in doubt, was, That having obſerved in *Florence*, and elſewhere, thoſe Ponds into which the rain-water, falling from the houſe, is conveyed through the Common-ſhores: And that they are not thereby ever filled, but that they ſwallow all that abundance of water, that runs into them by thoſe conveyances which ſerve them with water; inſomuch that thoſe conveyances which in time of drought maintain the Pond, when there comes new abundance of water into the Pond, they drink it up, and ſwallow it: A like effect might alſo fall out in the Lake, in which there being many veins (as it is very likely) that maintain and feed the Lake; theſe veins might imbibe the new addition of the Rain-water, and ſo by that means annull the riſing; or elſe diminiſh it in ſuch ſort, as to render it inobſervable. But this difficulty was eaſily reſolved by conſidering my Treatiſe of the meaſure of Running-Waters; foraſmuch as having demonſtrated, that the abatement of a Lake beareth the reciprocal proportion to the velocity of the Emiſſary, which the meaſure of the Section of the Emiſſary of the Lake, hath to the meaſure of the ſurface of the Lake: making the calculation and account, though in groſs; by ſuppoſing that its veins were ſufficiently large, and that the velocity in them were notable in drinking up the water of the Lake; yet I found nevertheleſs, that many weeks and moneths would be ſpent in drinking up the new-come abundance of water by the rain, ſo that I reſted ſure, that the riſing would enſue, as in effect it did.

And becauſe many of accurate judgement, have again cauſed me to queſtion this riſing, ſetting before me, that the Earth being parched by the great drought, that had ſo long continued, it might be, that that Bank of Earth which environed the brink of the Lake, being dry, and imbibing great abundance of Water

from

from the increaſing Lake, would not ſuffer it to increaſe in height: I ſay therefore, that if we would rightly conſider this doubt here propoſed, we ſhould, in the very conſideration of it, ſee it reſolved; for, it being ſuppoſed that that liſt or border of Banks which was to be occupied by the increaſe of the Lake, be a Brace in breadth quite round the Lake, and that by reaſon of its dryneſs it ſucks in water, and that by that means this proportion of water co-operates not in raiſing of the Lake: It is abſolutely neceſſary on the other hand, that we conſider, That the Circuit of the water of the Lake being thirty miles, as its commonly held, that is to ſay, Ninety thouſand Braces of *Florence* in compaſs; and therefore admitting for true, that each Brace of this Bank drink two quarts of water, and that for the ſpreading it require three quarts more, we ſhall finde, that the whole agregate of this portion of water, which is not imployed in the railing of the Lake, will be four hundred and fifty thouſand Quarts of water; and ſuppoſing that the Lake be ſixty ſquare miles, three thouſand Braces long, we ſhall finde, that to diſpence the water poſſeſt by the Bank about the Lake, above the total ſurface of the Lake, it ought to be ſpread ſo thin, that one ſole quart of water may over-ſpread ten thouſand ſquare Braces of ſurface: ſuch a thinneſs, as muſt much exceed that of a leaf of beaten Gold, and alſo leſs than that skin of water which covers the Bubbles of it: and ſuch would that be, which thoſe men would have ſubſtracted from the riſing of the Lake: But again, in the ſpace of a quarter of an hour at the beginning of the rain, all that Bank is ſoaked by the ſaid rain, ſo that we need not for the moiſtning of it, imploy a drop of that water which falleth into the Lake. Beſides we have not brought to account that abundance of water which runs in time of rain into the Lake, from the ſteepneſs of the adjacent Hills and Mountains; which would be enough to ſupply all our occaſions: So that, neither ought we for this reaſon to queſtion our pretended riſing. And this is what hath fallen in my way touching the conſideration of the *Thraſimenian* Lake.

After which, perhaps ſomewhat raſhly, wandring beyond my bounds, I proceeded to another contemplation, which I will relate to you, hoping that you will receive it, as collected with theſe cautions requiſite in ſuch like affairs; wherein we ought not too poſitively to affirm any thing of our own heads for certain, but ought to ſubmit all to the ſound and ſecure deliberation of the Holy Mother-Church, as I do this of mine, and all others; moſt ready to change my judgement, and conform my ſelf alwaies to the deliberations of my Superiors. Continuing

ing therefore my above-ſaid conceit about the riſing of the water in the glaſs tried before, it came into my minde, that the forementioned rain having been very gentle, it might well be, that if there ſhould have faln a Rain fifty, an hundred, or a thouſand times greater than this, and much more intenſe (which would inſue as oft as thoſe falling drops were four, five or ten times bigger than thoſe of the above-mentioned rain, keeping the ſame number) in ſuch a caſe its manifeſt, that in the ſpace of an hour the Water would riſe in our Glaſs, two, three, and perhaps more Yards or Braces; and conſequently, if ſuch a Raine ſhould fall upon a Lake, that the ſaid Lake would riſe, according to the ſame rate: And likewiſe, if ſuch a Rain were univerſall, over the whole Terreſtriall Globe, it would neceſſarily, in the ſpace of an hour, make a riſing of two, or three braces round about the ſaid Globe. And becauſe we have from Sacred Records, that in the time of the Deluge, it rained fourty dayes and fourty nights; namely, for the ſpace of 960 houres; its clear, that if the ſaid Rain had been ten times bigger than ours at *Perugia*, the riſing of the Waters above the Terreſtrial Globe would reach and paſs a mile higher than the tops of the Hills and Mountains that are upon the ſuperficies of the Earth; and they alſo would concur to increaſe the riſe. And therefore I conclude, that the riſe of the Waters of the Deluge have a rational congruity with natural Diſcourſes, of which I know very well that the eternal truths of the Divine leaves have no need; but however I think ſo clear an agreement is worthy of our conſideration, which gives us occaſion to adore and admire the greatneſſe of God in his mighty Works, in that we are ſometimes able, in ſome ſort, to meaſure them by the ſhort Standard of our Reaſon.

Many Leſſons alſo may be deduced from the ſame Doctrine, which I paſſe by, for that every man of himſelf may eaſily know them, having once ſtabliſhed this Maxime; That it is not poſſible to pronounce any thing, of a certainty, touching the quantity of Running Waters, by conſidering only the ſingle vulgar meaſure of the Water without the velocity; and ſo on the contrary, he that computes only the velocity, without the meaſure, ſhall commit very great errours; for treating of the meaſure of Running Waters, it is neceſſary, the water being a body, in handling its quantity, to conſider in it all the three dimenſions of breadth, depth, and length: the two firſt dimenſions are obſerved by all in the common manner, and ordinary way of meaſuring Running Waters; but the third dimenſion of length is omitted; and haply ſuch an overſight is committed, by reaſon the length of Running

ning Water is reputed in ſome ſenſe infinite, in that it never ceaſeth to move away, and as infinite is judged incomprehenſible; and ſuch as that there is no exact knowledge to be had thereof; & ſo there comes to be no account made thereof; but if we ſhould make ſtrict reflection upon our conſideration of the velocity of Water, we ſhould find, that keeping account of the ſame, there is a reckoning alſo made of the length; foraſmuch as whilſt we ſay, the Water of ſuch a Spring runs with the velocity of paſſing a thouſand or two thouſand paces an hour: this in ſubſtance is no other than if we had ſaid, ſuch a Fountain diſchargeth in an hour a Water of a thouſand or two thouſand paces long. So that, albeit the total length of Running water be incomprehenſible, as being infinite, yet nevertheleſſe its rendered intelligible by parts in its velocity. And ſo much ſufficeth to have hinted about this matter, hoping to impart on ſome other occaſion other more accurate Obſervations in this affair.

LAUS DEO.

GEOMETRICAL DEMONSTRATIONS OF THE MEASURE OF Running Waters.

BY

D. BENEDETTO CASTELLI,
Abbot of CASSINA, and Mathematician to
P. *URBAN. VIII.*

DEDICATED

To the most Illustrious, and most Excellent Prince

DON THADDEO BARBERINI,
PRINCE OF
PALESTRINA,
AND
GENERAL of the HOLY CHURCH.

LONDON,
Printed *Anno Domini*, MDCLXI.

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OF THE MENSURATION OF Running Waters.

SUPPOSITION I.

LEt it be ſuppoſed, that the banks of the Rivers of which we ſpeak be erected perpendicular to the plane of the upper ſuperficies of the River.

SUPPOSITION II.

WE ſuppoſe that the plane of the bottome of the River, of which we ſpeak is at right angles with the banks.

SUPPOSITION III.

IT is to be ſuppoſed, that we ſpeak of Rivers, when they are at ebbe, in that ſtate of ſhallowneſſe, or at flowing in that ſtate of deepneſſe, and not in their tranſition from the ebbe to the flowing, or from the flowing to the ebbe.

Declaration of Termes.

FIRST.

IF a River ſhall be cut by a Plane at right angles to the ſurface of the water of the River, and to the banks of the River, that ſame dividing Plane we call the Section of the River; and this Section, by the Suppoſitions above, ſhall be a right angled Parallelogram.

SECOND.

WE call thoſe Sections equally Swift, by which the water runs with equal velocity; and more ſwift and leſs ſwift that Section of another, by which the water runs with greater or leſſe velocity.

AXIOME I.

SEctions equal, and equally ſwift, diſcharge equal quantities of Water in equal times.

AXIOME II.

SEctions equally ſwift, and that diſcharge equal quantity of Water, in equal time, ſhall be equal.

AXIOME III.

SEctions equal, and that diſcharge equal quantities of Water in equal times, ſhall be equally ſwift.

AXIOME IV.

WHen Sections are unequal, but equally ſwift, the quantity of the Water that paſſeth through the firſt Section, ſhall have the ſame proportion to the quantity that paſſeth through the Second, that the firſt Section hath to the ſecond Section. Which is manifeſt, becauſe the velocity being the ſame, the difference of the Water that paſſeth ſhall be according to the difference of the Sections.

AXIOME V.

IF the Sections ſhall be equal, and of unequal velocity, the quantity of the Water that paſſeth through the firſt, ſhall have the ſame proportion to that which paſſeth through the ſecond, that the velocity of the firſt Section, ſhall have to the velocity of the ſecond Section. Which alſo is manifeſt, becauſe the Sections being equal, the difference of the Water which paſſeth, dependeth on the velocity.

PETITION.

A Section of a River being given, we may ſuppoſe another equal to the given, of different breadth, heigth, and velocity.

PRO-

PROPOSITION I.

The Sections of the same River discharge equal quantities of Water in equal times, although the Sections themselves be unequal.

LEt the two Sections be A and B, in the River C, running from A, towards B; I say, that they discharge equal quantity of Water in equal times; for if greater quantity of Water should pass through A, than passeth through B, it would

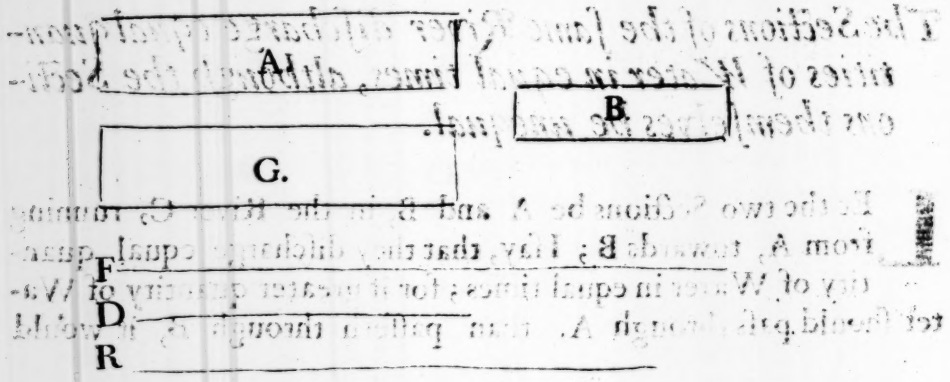
follow that the Water in the intermediate space of the River C, would increase continually, which is manifestly false, but if more Water should issue through the Section B, than entreth at the Section A, the Water in the intermediate space C, would grow continually less, and alwaies ebb, which is likewise false; therefore the quantity of Water that passeth through the Section B, is equal to the quantity of Water which passeth through the Section A, and therefore the Sections of the same River discharge, *&c.* Which was to be demonstrated.

PROPOSITION II.

In two Sections of Rivers, the quantity of the Water which passeth by one Section, is to that which passeth by the second, in a Proportion compounded of the proportions of the first Section to the second, and of the velocitie through the first, to the velocitie of the second.

LEt A, and B be two Sections of a River; I say, that the quantity of Water which passeth through A, is to that which passeth through B, in a proportion compounded of the proportions of the first Section A, to the Section B; and of the velocity through A, to the velocity through B: Let a Section be supposed

ſuppoſed equal to the Section A, in magnitude; but of velocity equal to the Section B, and let it be G; and as the Section A is



to the Section B, ſo let the line F be to the line D; and as the velocity A, is to the velocity by B, ſo let the line D be to the line R: Therefore the Water which paſſeth thorow A, ſhall be to that which paſſeth through G (in regard the Sections A and G are of equal bigneſs, but of unequal velocity) as the velocity through A, to the velocity through G; But as the velocity through A, is to the velocity through G, ſo is the velocity through A, to the velocity through B; namely, as the line D, to the line R: therefore the quantity of the Water which paſſe the through A, ſhall be to the quantity which paſſeth through G, as the line D is to the line R; but the quantity which paſſeth through G, is to that which paſſeth through B, (in regard the Sections G, and B, are equally ſwift) as the Section G to the Section B; that is, as the Section A, to the Section B; that is, as the line F, to the line D: Therefore by the equal and perturbed proportionality, the quantity of the Water which paſſeth through A, hath the ſame proportion to that which paſſeth through B, that the line F hath to the line R; but F to R, hath a proportion compounded of the proportions of F to D, and of D to R; that is, of the Section A to the Section B; and of the velocity through A, to the velocity through B: Therefore alſo the quantity of Water which paſſeth through the Section A, ſhall have a proportion to that which paſſeth through the Section B, compounded of the proportions of the Section A, to the Section B, and of the velocity through A, to the velocity through B: And therefore in two Sections of Rivers, the quantity of Water which paſſeth by the firſt, *&c.* which was to be demonſtrated.

COROLLARIE.

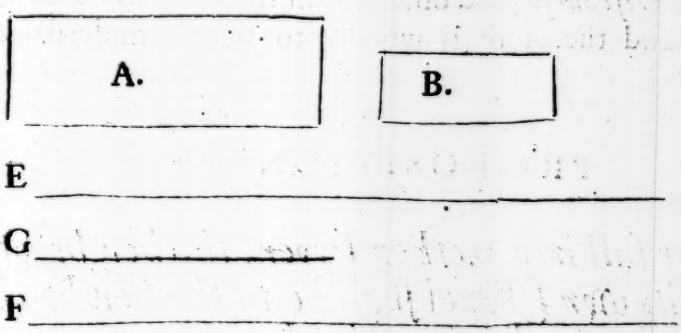
THe ſame followeth, though the quantity of the Water which paſſeth through the Section A, be equal to the quantity of Water which paſſeth through the Section B, as is manifeſt by the ſame demonſtration.

PROPO-

PROPOSITION III.

In two Sections unequal, through which paſs equal quantities of Water in equal times; the Sections have to one another, reciprocal proportion to their velocitie.

LEt the two unequal Sections, by which paſs equal quantities of Water in equal times be A, the greater; and B, the leſſer: I ſay, that the Section A, ſhall have the ſame Proportion to the Section B, that reciprocally the velocity through B, hath to the velocity through A; for ſuppoſing that as the Water that paſſeth through A, is to that which paſſeth through B, ſo is the



line E to the line F: therefore the quantity of water which paſſeth through A, being equal to that which paſſeth through B, the line E ſhall alſo be equal to the line F: Suppoſing moreover, That as the Section A, is to the Section B, ſo is the line F, to the line G; and becauſe the quantity of water which paſſeth through the Section A, is to that which paſſeth through the Section B, in a proportion compoſed of the proportions of the Section A, to the Section B, and of the velocity through A, to the velocity through B; therefore the line E, ſhall be the line to F, in a proportion compounded of the ſame proportions; namely, of the proportion of the Section A, to the Section B, and of the velocity through A, to the velocity through B; but the line E, hath to the line G, the proportion of the Section A, to the Section B, therefore the proportion remaining of the line G, to the line F, ſhall be the proportion of the velocity through A, to the velocity through B; therefore alſo the line G, ſhall be to the line E, as the velocity by A, to the velocity by B: And converſly, the velocity through B, ſhall be to the velocity through A, as the line E, to the line G; that is to ſay, as the Section A, to the Section B, and therefore in two Sections, &c. which was to be demonſtrated.

COROLLARIE.

HEnce it is manifeſt, that Sections of the ſame River (which are no other than the vulgar meaſures of the River) have betwixt themſelves reciprocal proportions to their velocities; for in the firſt Propoſition we have demonſtrated that the Sections of the ſame River, diſcharge equal quantities of Water in equal times; therefore, by what hath now been demonſtrated, the Sections of the ſame River ſhall have reciprocal proportion to their velocities; And therefore the ſame running water changeth meaſure, when it changeth velocity; namely, increaſeth the meaſure, when it decreaſeth the velocity, and decreaſeth the meaſure, when it increaſeth the velocity.

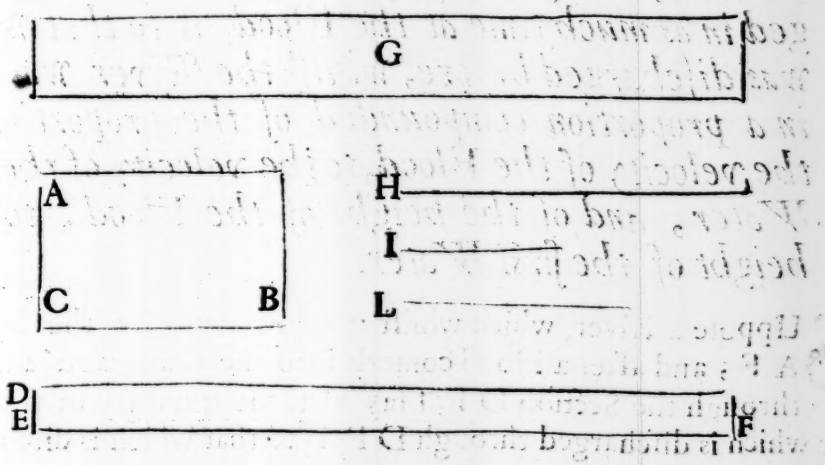
On which principally depends all that which hath been ſaid above in the *Diſcourſe*, and obſerved in the *Corollaries* and *Appendixes*; and therefore is worthy to be well underſtood and heeded.

PROPOSITION IV.

If a River fall into another River, the height of the firſt in its own Chanel ſhall be to the height that it ſhall make in the ſecond Chanel, in a proportion compounded of the proportions of the breadth of the Chanel of the ſecond, to the breadth of the Chanel of the firſt, and of the velocitie acquired in the Chanel of the ſecond, to that which it had in its proper and firſt Chanel.

LEt the River A B, whoſe height is A C, and breadth C B, that is, whoſe Section is A C B; let it enter, I ſay, into another River as broad as the line E F, and let it therein make the riſe or height D E, that is to ſay, let it have its Section in the River whereinto it falls D E F; I ſay, that the height A C hath to the height D E the proportion compounded of the proportions of the breadth E F, to the breadth C B, and of the velocity through D F, to the velocity through A B. Let us ſuppoſe the Section G, equal in velocity to the Section A B, and in breadth equal to E F, which carrieth a quantity of Water equal to that which the Section A B carrieth, in equal times, and conſequently, equal to that which D F carrieth. Moreover, as the breadth E F is to the breadth C B, ſo let the line H be to the

the line I; and as the velocity of D F is to the velocity of A B, ſo let the line I be to the line L; becauſe therefore the two Sections A B and G are equally ſwift, and diſcharge equal quantity of Water in equal times, they ſhall be equal Sections; and

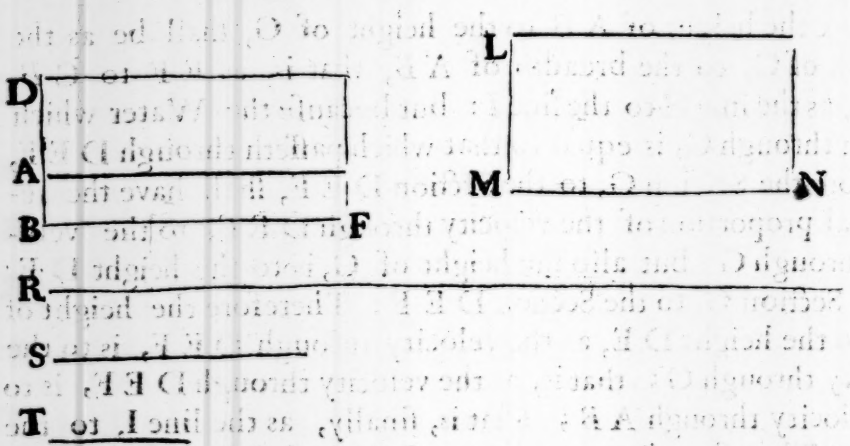


therefore the height of A *B* to the height of G, ſhall be as the breadth of G, to the breadth of A *B*, that is, as E F to C *B*, that is, as the line H to the line I: but becauſe the Water which paſſeth through G, is equal to that which paſſeth through D E F, therefore the Section G, to the Section D E F, ſhall have the reciprocal proportion of the velocity through D E F, to the velocity through G; but alſo the height of G, is to the height D E, as the Section G, to the Section D E F: Therefore the height of G, is to the height D E, as the velocity through D E F, is to the velocity through G; that is, as the velocity through D E F, is to the velocity through A *B*; That is, finally, as the line I, to the line L; Therefore, by equal proportion, the height of *A B*, that is, A C, ſhall be to the height D E; as H to L, that is, compounded of the proportions of the breadth E F, to the breadth C *B*, and of the velocity through D F, to the velocity through A *B*: So that if a River fall into another River, &c. which was to be demonſtrated.

PROPOSITION V.

If a River discharge a certain quantitie of Water in a certain time; and after that there come into it a Flood, the quantity of Water which is discharged in as much time at the Flood, is to that which was discharged before, whilst the River was low, in a proportion compounded of the proportions of the velocity of the Flood, to the velocity of the first Water, and of the height of the Flood, to the height of the first Water.

SUppose a River, which whilst it is low, runs by the Section A F; and after a Flood cometh into the same, and runneth through the Section D F, I say, that the quantity of the Water which is discharged



through A F, in a proportion compounded of the proportions of the velocity through D F, to the velocity through A F, and of the height D *B*, to the height A *B*; As the velocity through DF is to the velocity through A F, so let the line R, to the line S; and as the height D *B* is to the height A *B*, so let the line S, to the line T; and let us suppose a Section L M N, equal to D F in height and breadth; that is L M equal to D *B*, and M N equal to *B F*; but let it be in velocity equal to the Section A F, therefore the quantity of Water which runneth through D F, shall be to that which runneth through LN, as the velocity through DF, is to the velocity through L N, that is, to the velocity through *A F*; and the line R being to the line S, as the velocity through D *F*, to the velocity through *A F*; therefore the quantity which runneth through D *F*, to that which runneth through L N, shall have the proportion of R to S; but the quantity which runneth through L N, to that which runneth through *A F*, (the Sections being

being equally ſwift) ſhall be in proportion as the Section *L N*, to the Section A F ; that is,as D B,to A B; that is as the line S, to the line T: Therefore by equal proportion, the quantity of the water which runneth through D F,ſhall be in proportion to that which runneth through A F,as R is to T; that is, compounded of the proportions of the height D B, to the height A B, and of the velocity through *D F*,to the velocity through *A F*;and therefore if a River diſcharge a certain quantity, *&c.* which was to be demonſtrated.

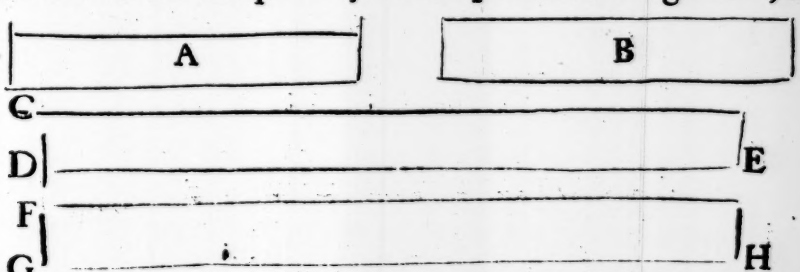
ANNOTATION.

THe ſame might have been demonſtrated by the ſecond Propoſition above demonſtrated, as is manifeſt.

PROPOSITION VI.

If two equal ſtreams of the ſame Torrent, fall into a River at divers times, the heights made in the River by the Torrent, ſhall have between themſelves the reciprocal proportion of the velocities acquired in the River.

LEt A and B, be two equal ſtreams of the ſame Torrent; which falling into a River at divers times, make the heights C D, and F G; that is the ſtream A, maketh the height C D, and the ſtream B, maketh the height F G; that is, Let their Sections in the River, into which they are fallen, be C E, and F H; I ſay, that the height C D, ſhall be to the height F G, in reciprocal proportion, as the velocity through F H, to the velocity through C E; for the quantity of water which paſſeth through A, being equal to the quantity which paſſeth through B, in equal times; alſo the quantity which paſſeth through C E, ſhall



be equal to that which paſſeth through F H: And therefore the proportion that the Section C E, hath to the Section F H; ſhall be the ſame that the velocity through F H, hath to the velocity through C E; But the Section C E, is to the Section F H, as C D, to F G, by reaſon they are of the ſame breadth: Therefore C D, ſhall be to F G, in reciprocal proportion, as the velocity through F H, is to the velocity through C E, and therefore if two equal ſtreams of the ſame Torrent, *&c.* which was to be demonſtrated.

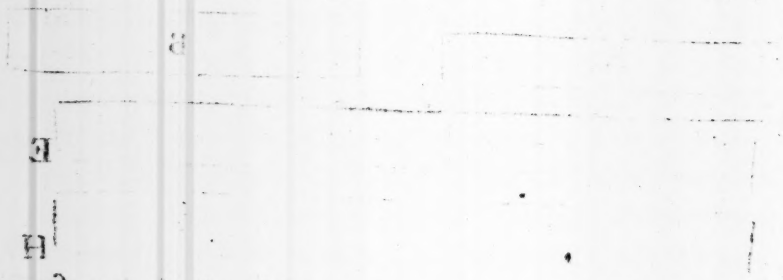
[illegible] the Section L N, to [illegible] that is [illegible] the line S, to [illegible] the quantity of the [illegible] proportion to [illegible] that is, compound [illegible] the height [illegible] and [illegible] and therefore [illegible] which was to be [illegible]

[illegible] by the [illegible]

[illegible]

If two equal streams of the same Torrent, fall into River at diverse times, the heights made in the River by the Torrent, shall have between themselves the reciprocal proportion of the velocities acquired in the River.

[illegible] two equal streams of the same Torrent [illegible] at diverse times, make the heights [illegible] the stream A, maketh the height C [illegible] B, [illegible] the height F G; that is, Let [illegible] River into which they are fallen, be C E, [illegible] C [illegible] shall be to the height F G, [illegible] through F H, to the velocity [illegible] quantity of water which passeth [illegible] quantity which passeth through B, [illegible] which passeth through C E, shall



[illegible] which passeth through F H: And therefore the proportion [illegible] Section C E, hath to the Section F H, shall be [illegible] velocity through F H, hath to the velocity [illegible] C E, is to the Section F H, as [illegible] the same breadth: Therefore [illegible] reciprocal proportion, as the velocity [illegible] through C E, and therefore if two equal streams [illegible] which was to be demonstrated.

OF THE MENSURATION OF Running Waters.

Lib. II.

Aving, in the cloſe of my Treatiſe of the Menſuration of Running Waters promiſed to declare upon another occaſion other particulars more obſcure, and of very great concern upon the ſame argumement: I now do perform my promiſe on the occaſion that I had the paſt year 1641. to propound my thoughts touching the ſtate of the Lake of *Venice*, a buſineſs certainly moſt important, as being the concernment of that moſt noble and moſt admirable City; and indeed of all *Italy*, yea of all *Europe*, *Aſia*, & *Africa*; & one may truly ſay of all the whole World. And being to proceed according to the method neceſſary in Sciences, I wil propoſe, in the firſt place certain Definitions of thoſe Terms whereof we are to make uſe in our Diſcourſe: and then, laying down certain Principles we will demonſtrate ſome Problemes and Theoremes neceſſary for the underſtanding of thoſe things which we are to deliver; and moreover, recounting ſundry caſes that have happened, we will prove by practice, of what utility this contemplation of the Meaſure of Running Waters is in the more important affairs both Publique and Private.

DEFINITION I.

TWo Rivers are ſaid to move with equal velocity, when in equal times they paſſe ſpaces of equal length.

DEFINITION II.

RIvers are ſaid to move with like velocity, when their proportional parts do move alike, that is, the upper parts alike to the upper, and the lower to the lower; ſo that if the upper part of one River ſhall be more ſwift than the upper part of another; then alſo the lower part of the former ſhall be more ſwift than the part correſpondent to it in the ſecond, proportionally.

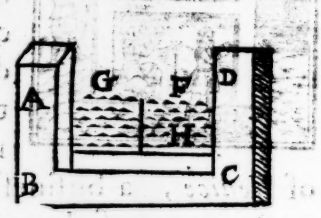
DEFI-

DEFINITON III.

TO measure a River, or running Water, is in our sense to finde out how many determinate measures, or weights of Watet in a given time passeth through the River, or Channel of the Water that is to be measured.

DEFINITION IV.

IF a Machine be made either of Brick, or of Stone, or of Wood, so composed that two sides of the said Machine be placed at right angles upon the ends of a third side, that is supposed to be placed in the bottom of a River, parallel to the Horizon, in such a manner, that all the water which runneth through the said River, passeth thorow the said Machine: And if all the water coming to be diverted that runneth through the said River, the upper superficies of that third side placed in the bottom do remain uncovered and dry, and that the dead water be not above it; This same Machine shall be called by us * REGULATOR: And that third side of the Machine which standeth Horizontally is called the bottom of the Regulator; and the other two sides, are called the banks of the Regulator; as is seen in this first Figure: A B C D, shall be the Regulator; B C the bottom; and the other two sides A B, and C D are its banks.



* Or Sluice.

DEFINITION V.

BY the quick height, we mean the Perpendicular from the upper superficies of the River, unto the upper superficies of the bottom of the Regulator; as in the foregoing Figure the line. G H.

DEFINITION VI.

IF the water of a River be supposed to be marked by three sides of a Regulator, that Rightangled Parallelogram comprehended between the banks of the Regulator, and the bottom, and the superficies of the Water is called a Section of the River.

ANNOTA.

ANNOTATION.

HEre it is to be noted, that the River it ſelf may have ſundry and divers heights, in ſeveral parts of its Chanel, by reaſon of the various velocities of the water, and its meaſures; as hath been demonſtrated in the firſt book.

SUPPOSITION I.

IT is ſuppoſed, that the Rivers equal in breadth, and quick height, that have the ſame inclination of bed or bottom, ought alſo to have equal velocities, the accidental impediments being removed that are diſperſed throughout the courſe of the water, and abſtracting alſo from the external windes, which may velocitate, and retard the courſe of the water of the River.

SUPPOSITION II.

LEt us ſuppoſe alſo, that if there be two Rivers that are in their beds of equal length, and of the ſame inclination, but of quick heights unequal, they ought to move with like velocity, according to the ſenſe explained in the ſecond definition.

SUPPOSITION III.

BEcauſe it will often be requiſite to meaſure the time exactly in the following Problems, we take that to be an excellent way to meaſure the time, which was ſhewed me many years ſince by *Signore Galilæo Galilæi*, which is as followeth.

A ſtring is to be taken three Roman feet long, to the end of which a Bullet of Lead is to be hanged, of about two or three ounces; and holding it by the other end, the Plummet is to be removed from its perpendicularity a Palm, more or leſs, and then let go, which will make many ſwings to and again, paſſing and repaſſing the Perpendicular, before that it ſtay in the ſame: Now it being required to meaſure the time that is ſpent in any whatſoever operation, thoſe vibrations are to be numbred, that are made whilſt the work laſteth; and they ſhall be ſo many ſecond minutes of an hour, if ſo be, that the ſtring be three Roman feet long, but in ſhorter ſtrings, the vibrations are more frequent, and in longer, leſs frequent; and all this ſtill followeth, whether the Plummet be little or much removed from its Perpendicularity, or whether the weight of the Lead be greater or leſſer.

Theſe things being pre-ſuppoſed, we will lay down ſome fa-

miliar Problems, from which we ſhall paſs to the Notions and queſtions more ſubtil and curious; which will alſo prove profitable, and not to be ſleighted in this buſineſs of Waters.

PROPOSITION I. PROBLEME I.

A Chanel of Running-Water being given, the breadth of which paſsing through a Regulator, is three Palms; and the height one Palm, little more or leſs, to meaſure what water paſſeth through the Regulator in a time given.

FIrſt, we are to dam up the Chanel; ſo that there paſs not any water below the Dam; then we muſt place in the ſide of the Chanel, in the parts above the Regulator three, or four, or five Bent-pipes, or Syphons, according to the quantity of the water that runneth along the Chanel; in ſuch ſort, as that they may drink up, or draw out of the Chanel all the water that the Chanel beareth (and then ſhall we know that the Syphons drink up all the water, when we ſee that the water at the Dam doth neither riſe higher, nor abate, but alwaies keepeth in the ſame Level.) Theſe things being prepared, taking the Inſtrument to meaſure the time, we will examine the quantity of the water that iſſueth by one of thoſe Syphons in the ſpace of twenty vibrations, and the like will we do one by one with the other Syphons; and then collecting the whole ſumme, we will ſay, that ſo much is the water that paſſeth and runneth thorow the Regulator or Chanel (the Dam being taken away) in the ſpace of twenty ſecond minutes of an hour; and calculating, we may eaſily reduce it to hours, dayes, months, and years: And it hath fallen to my turn to meaſure this way the waters of Mills and Fountains, and I have been well aſſured of its exactneſs, by often repeating the ſame work.

CONSIDERATION.

AND this method muſt be made uſe of in meaſuring the waters, that we are to bring into Conducts, and carry into Cities and Caſtles, for Fountains; and that we may be able afterwards to divide and ſhare them to particular perſons juſtly; which will prevent infinite ſuits and controverſies that every day happen in theſe matters..

PROPO-

PROPOSITION II. THEOREM I.

If a River moving with ſuch a certain velocitie through its Regulator, ſhall have a given quick height, and afterwards by new water ſhall increaſe to be double, it ſhall alſo increaſe double in velocitie.

LEt the quick height of a River in the Regulator A B C D, be the perpendicular F B, and afterwards, by new water that is added to the River, let the water be ſuppoſed to be raiſed to G, ſo that G B may be double to E B. I ſay, that all the water G C ſhall be double in velocity to that of E C: For the water G F, having for its bed the bottom E F, equally inclined as the bed B C, and its quick height G E being equal to the quick height E C, and having the ſame breadth B C, it ſhall have of it ſelf a velocity equal to the velocity of the firſt water F C: but becauſe, beſides its own motion, which is imparted to it by the motion of the water E C, it hath alſo over and above its own motion, the motion of E C. And becauſe the two waters G C, and E C, are alike in velocity, by the third Suppoſition; therefore the whole water G C ſhall be double in velocity to the water E C; which was that which we were to demonſtrate.

This demonſtration is not here inſerted, as perfect, the Authour having by ſeveral letters to his friends confeſſed himſelf unſatisfied therewith; and that he intended not to publiſh the Theorem *without a more ſolid demonſtration, which he was in hope to light upon. But being overtaken by Death, he could not give the finiſhing touch either to this, or to the reſt of the ſecond Book. In conſideration of which, it ſeemed good to the Publiſher of the ſame, rather to omit it, than to do any thing contrary to the mind of the Authour. And this he hints, by way of advertiſement, to thoſe that have Manuſcript Copies of this Book, with the ſaid demonſtration. For this time let the Reader content himſelf with the knowledge of ſo ingenious and profitable a Concluſion; of the truth of which he may, with ſmall expence and much pleaſure, be aſſured by means of the experiment to be made in the ſame manner, with that which is laid down in the ſecond Corollary of*

the fourth Theorem *of this, with its Table, and the uſe thereof annexed.*

COROLLARIE

HEnce it followeth, that when a River increaſeth in quick height by the addition of new water, it alſo increaſeth in velocity; ſo that the velocity hath the ſame proportion to the velocity that the quick height hath to the quick height; as may be demonſtrated in the ſame manner.

PROPOS. III. PROBLEME II.

A Chanel of Water being given whoſe breadth exceeds not twenty Palms, or thereabouts, and whoſe quick height is leſs than five Palms, to meaſure the quantity of the Water that runneth thorow the Chanel in a time given.

PLace in the Chanel a Regulator, and obſerve the quick height in the ſaid Regulator; then let the water be turned away from the Chanel by a Chanellet of three or four Palms in breadth, or thereabouts: And that being done, meaſure the quantity of the water which paſſeth thorow the ſaid Chanellet, as hath been taught in the ſecond Propoſition; and at the ſame time obſerve exactly how much the quick height ſhall be abated in the greater Chanel, by means of the diverſion of the Chanellet; and all theſe particulars being performed, multiply the quick height of the greater Chanel into it ſelf, and likewiſe multiply into it ſelf the leſſer height of the ſaid bigger Chanel, and the leſſer ſquare being taken, from the greater, the remainder ſhall have the ſame proportion to the whole greater ſquare, as the water of the Chanellet diverted, hath to the water of the bigger Chanel: And becauſe the water of the Chanellet is known by the Method laid down in the firſt Theorem, and the terms of the Theorem being alſo known, the quantity of the water which runneth thorow the bigger Chanel, ſhall be alſo known by the Golden Rule, which was that that was deſired to be known. We will explain the whole buſineſs by an example.

Let a Chanel be, for example, 15 Palms broad, its quick height before its diverſion by the Chanellet ſhall be ſuppoſed to be 24 inches; but after the diverſion, let the quick height of the Chanel be onely 22 inches. Therefore the greater height to the leſſer, is as the number 11. to 12. But the ſquare of 11. is 121, and the ſquare of 12. is 144, the difference between the ſaid leſſer

ſquare

ſquare and the greater is 23. Therefore the diverted water, is to the whole water, as 23. to 144: which is well near as 1 to $6\frac{6}{23}$: and that is the proportion that the quantity of the water which runneth through the Chanellet ſhall have, to all the water that runneth thorow the great Chanel. Now if we ſhould finde by the Rule mentioned above in the firſt Propoſition; that the quantity of the water that runneth through the Chanellet, is *v. g.* an hundred Barrels, in the ſpace of 15 ſecond minutes of an hour, it is manifeſt, that the water which runneth through the great Chanel in the ſaid time of 35 min. ſec. ſhall be about 600 Barrels.

The ſame operation performed another way.

AND becauſe very often in applying the Theory to Practice it happeneth, that all the neceſſary particulars in the Theory cannot ſo eaſily be put in execution; therefore we will here add another way of performing the ſame Problem, if it ſhould chance to happen that the Chanellet could not commodiouſly be diverted from the great Chanel, but that it were eaſier for the water of another ſmaller Chanel to be brought into the greater Chanel; which water of the ſmaller Chanel might be eaſily meaſured, as hath been ſhewen in the firſt Probleme; or in caſe that there did fall into a greater Chanel, a leſſer Chanel that might be diverted and meaſured. Therefore I ſay in the firſt caſe, If we would meaſure the quantity of the water that runneth in a certain time thorow the greater Chanel, into which another leſſer Chanel that is meaſurable may be brought, we muſt firſt exactly meaſure the Chanellet, and then obſerve the quick height of the greater Chanel, before the introduction of the leſſer; and having brought in the ſaid Chanellet, we muſt agnin find the proportion that the water of the Chanellet hath to all the water of the great Chanel; for theſe terms of the proportion being known, as alſo the quantity of the water of the Chanellet, we ſhall alſo come to know the quantity of the water that runneth thorow the great Chanel. It is likewiſe manifeſt, that we ſhall obtain our intent, if the caſe were that there entered into the great Chanel, another leſſer Chanel that was meaſurable, and that might be diverted.

CONSIDERATION.

IT would be neceſſary to make uſe of this Doctrine in the diſtribution of the waters that are imploy'd to overflow the fields, as is uſed in the *Breſcian*, *Cremoneſe*, *Bergamaſe*, *Lodigian*, *Mila-*

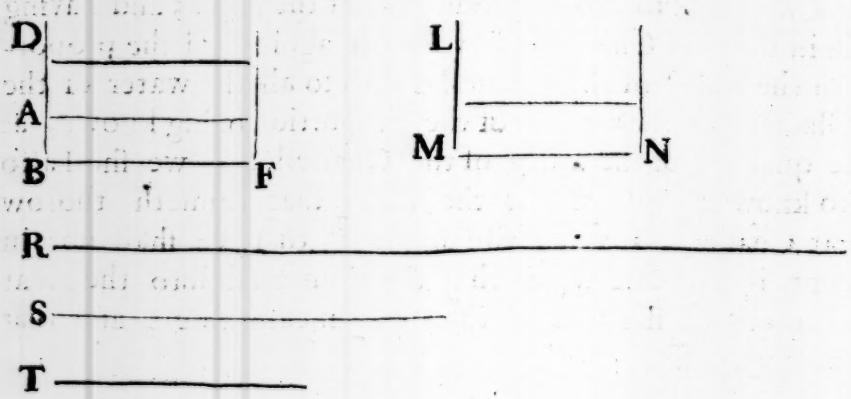
neſe,

neſe territories, and many other places, where very great ſuits and differences ariſe, which not being to be determined with intelligible reaſons, come oftentimes to be decided, by force of armes; and inſtead of flowing their Grounds with Waters, they cruelly flow them with the ſhedding of humane blood, impiouſly inverting the courſe of Peace and Juſtice, ſowing ſuch diſorders and feuds, as that they are ſometimes accompanied with the ruine of whole Cities, or elſe unprofitably charge them with vain, and ſometimes prejudicial expences.

PROPOS. IV. THEOR. II.

If a River increaſe in quick height, the quantitie of Water which the River diſchargeth after the increaſe, hath the Proportion compounded of the Proportions of the Quick height to the Quick height, and of the velocity to the velocity.

LEt there be a River, which whilſt it is low, runneth thorow the Regulator D F, with the Quick height A B, and afterwards let a Flood come; and then let it run with the height D B, I ſay, that the quantity of the Water that is diſcharged through D F, to that which diſchargeth through A F, hath the proportion compounded of the proportions of the velocity through D F to the velocity through A F, and of the height D B to the height A B. As the velocity through D F is to the velocity through A F, ſo let the line R be to the line S; and as the height D B is to the height A B; ſo let the line S be to the



line T. And let a Section be ſuppoſed L M N equal to the Section D F in height and length, but let it be in velocity equal to the Section A F. Therefore the quantity of the Water that runneth through D F to that which runneth through L N, ſhall be

as the velocity through D F, to the velocity of L N, that is, to the velocity through L N, that is, to the velocity through *A F*. therefore the quantity of Water which runneth through D *F*, to that which passeth through L N, shall have the proportion that R hath to S; but the quantity of the Water that runneth through L N, to that which runneth through *A F*; (the Sections being equally swift) shall have the proportion that the Section L N hath to the Section A F, that is, that the height *B* D hath to the height *B* A, that is, that S hath to Γ. Therefore, by equal proportion, the quantity of the Water which runneth by D F, to that which runneth by A F, shall have the proportion of R to T, that is, shall be compounded of the proportions of the height D *B*, to the height A *B*; and of the velocity through D F, to the velocity through A F. And therefore if a River increase in quick height, the quantity of the Water that runneth after the increase, to that which runneth before the increase, hath the proportion compounded, &c. Which was to be demonstrated.

COROLLARIE I.

HEnce it followeth, that we having shewn, that the quantity of the Water which runneth, whilst the River is high, to that which ran, whilst it was low, hath the proportion compounded of the velocity to the velocity, and of the height to the height. And it having been demonstrated, that the velocity to the velocity is as the height to the height; it followeth, I say, that the quantity of the Water that runneth, whilst the River is high, to that which runneth, whilst it is low, hath duplicate proportion of the height to the height, that is, the proportion that the squares of the heights have.

COROLLARIE II.

VPon which things dependeth the reason of that which I have said, in my second Consideration, that if by the diversion of $\frac{1}{3}$ of the Water that entereth by the Rivers into the Moor or Fen, the Water be abated such a measure, that same shall be only one third of its whole height; but moreover diverting the $\frac{1}{3}$, it shall abate two other thirds, a most principal point; and such, that its not having been well understood, hath caused very great disorders, and there would now, more than ever, follow extream dammage, if one should put in execution the diversion of the *Sile* and other Rivers; and it is manifest, that in the same manner, wherewith it hath been demonstrated, that the quantity of the Water increasing quadruple, the height would increase onely

double

double, and the quantity increasing nonuple, the height increaseth triple; so that, by adding to units all the odde numbers, according to their Series, the heights increase according to the natural progression of all the numbers, from units. As for example, there passing thorow a Regulator such a certain quantity of Water in one time; adding three of those measures, the quick height is two of those parts, which at first was one; and continuing to adde five of those said measures, the height is three of those parts which at first were one; and thus adding seven, and then nine, and then 11. and then 13, &c. the heights shall be 4. then 5, then 6. then 7, &c. And for the greater facility of the Work, we have described the following Table, of which we will declare the use: The Table is divided into three Series or Progressions of Numbers: the first Series containeth all the Numbers in the Natural Progression, beginning at a Unit, and is called the Series of the Heights; the second containeth all the odde numbers, beginning at an unit, and is called the Series of the Additions: the third containeth all the square numbers, beginning at an unit, and is called the Series of Quantity.

Heights.	1	1	2	3	4	5	6	7	8	9	10	11
Additions.	1	1	3	5	7	9	11	13	15	17	19	21
Quantities.	1	1	4	9	16	25	36	49	64	81	100	121

The use of the afore-mentioned Table.

First, if we suppose the whole quick height of a River of Running Water to be divided into any number of equal parts, at pleasure, and would abate the same one fift, by means of a division; let there be found in the Table in the Series of heights the number 5. the denominator of the part which the River is to abate, and take the number that is immediately under it in the row of Additions, which is 9. which let be substracted from the number 25. placed underneath the same in the row of Quantities, the remainder 16. signifieth that of the 25. parts of Water that ran in the River, whilst it was 5 measures high, there do onely run 16. parts; so that to make it abate $\frac{1}{5}$ it is necessary to take $\frac{9}{25}$ from the Water that the whole River did carry; so that with substracting somewhat more than one third of the Water of the River, it is abated but only one fift.

2. And thus, in the second place, if on the contrary, one would know how much water is to be added to the said River to make it increase one fift more in height, so as that it may run in the Regulator

Regulator 6. of thoſe parts high; of which it ran before but 5. let 6 be found in the row of heights, and let the number 11. ſtanding under the ſame be taken and added to the number 25. that is placed under the number 9. in the Additions, and 5. in the heights, and you ſhall have 36; which is the quantity of the water that runneth with the height of the River, when it is high 6 of thoſe parts, whereof it was before but 5.

3. But if it ſhould be deſired, to know how much water it is requiſite to add to make the River riſe ſo, as that it may run in height 8. of thoſe parts of which before it ran but 5; one ought to take the ſum of the number of the Series of Additions ſtanding under 8. 7. and 6, which are 15. 13. and 11. that is, 39. and this ſhall be the ſumme that muſt be added to 25: So that to make the River to run 8. of thoſe parts in height, of which it before did run 5, it will be neceſſary to add 39. of thoſe parts, of which the River before was 25.

4. Likewiſe the ſame Table giveth the quantity of water that runneth from time to time through a River, that increaſeth by the addition of new water to the ſame in one of its heights, the quantity of its water be known. As for example: If we knew that the River in one minute of an hour diſchargeth 2500. of thoſe meaſures of water, and runneth in height 5. parts in the Regulator, and afterwards ſhould ſee that it runneth 8 Palms high, finding in the row of quantity the number placed under 8. which is 64. we would ſay that the River heightned, carrieth of water 64. of thoſe parts whereof it carried before but 25; and becauſe before it carried 2500. meaſures, by the Golden Rule we will ſay, that the River carrieth 6400. of thoſe meaſures, of which before it carried 2500.

In this progreſs of Nature, is one thing really curious, and that at firſt ſight ſeemeth to be ſomewhat Paradoxal, that we proceeding ordinately in the diverſions and additions, with additions and diverſions ſo unequal, the abatings do notwithſtanding alwaies prove equal, and ſo do the riſings: And who would ever think that a River in height, *v. g.* 10. Palms, running and carrying an hundred meaſures in a minute of an hour, is to abate but one Palm, onely by the diverſion of 19. of thoſe meaſures; and then again, that the buiſineſs cometh to that paſs, that it abateth likewiſe a Palm by the diverſion of three onely of thoſe meaſures, nay, by the diverſion of but one meaſure? and yet it is moſt certain: And this truth meets with ſo manifeſt proofs in experience, that it is very admirable! And for the full ſatisfaction of thoſe, who not being able to comprehend ſubtil demonſtrations, deſire to be clearly inform'd by the matters of fact, and to ſee with their bobily eyes, and touch with their hands, what their underſtanding and reaſon cannot reach unto: I will hear add another very eaſie way to reduce all to an experiment, the

which may be made in little, in great, or in very great; of which I make uſe frequently, to the admiration of ſuch as ſee it.

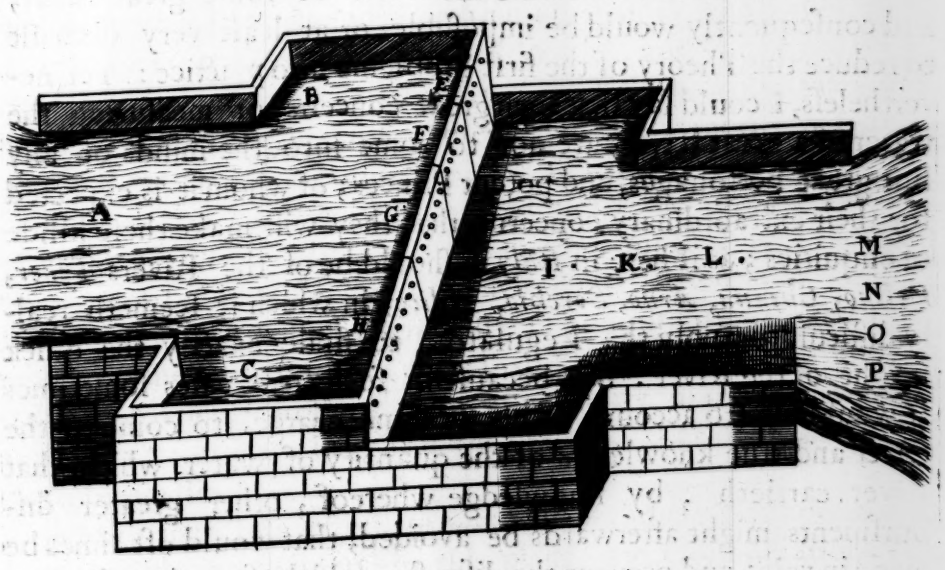
I prepared an hundred Siphons, or, if you will, bowed Pipes, all equal; and placed them at the brim of a Veſſel, wherein the water is kept at one and the ſame level (whether all the Syphons work, or but a certain number of them) the mouths by which the water iſſueth being all placed in the ſame level, parallel to the Horizon; but lower in level than the water in the Veſſel; and gathered all the water falling from the Syphons into another Veſſel ſtanding lower than the former, I made it to run away thorow a Chanel, in ſuch manner inclined, that wanting water from the Syphons, the ſaid Chanel remained quite dry.

And this done, I meaſured the quick height of the Chanel with care, and afterwards divided it exactly into 10 equal parts, and cauſing 19. of thoſe Syphons to be taken away, ſo that the Chanel did not run water, ſave onely with 81 of thoſe Syphons, I again obſerved the quick height of the water in the ſame ſite obſerved before, and found that its height was diminiſhed preciſely the tenth part of all its firſt height; and thus continuing to take away 17. other Syphons, the height was likewiſe diminiſhed $\frac{1}{10}$. of all its firſt quick height; and trying to take away 15. Syphons, then 13, then 11, then 9, then 7, then 5, and then 3. alwaies in theſe diverſions, made in order as hath been ſaid, there enſued ſtill an abatement of $\frac{1}{10}$. of the whole height.

And here was one thing worthy of obſervation, that the water encreaſing in [*or through*] the Chanel, its quick height was different in different ſites of the Chanel, that is ſtill leſſer, the more one approached to the Out-let; notwithſtanding which the abatement followed in all places proportionably, that is in all its ſites the firſt part of the height of that ſite diminiſhed: And moreover the water iſſued from the Chanel, and dilated into a broader courſe, from which likewiſe having divers Out-lets and Mouths; yet nevertheleſs in that breadth alſo the quick heights ſucceſſively varied and altered in the ſame proportions. Nor did I here deſiſt my obſervation, but the water being diminiſhed, that iſſued from the Syphons, and there being but one of them left that diſcharged water; I obſerved the quick height that it made in the above-ſaid ſites, (the which was likewiſe $\frac{1}{10}$. of all the firſt height) there being added to the water of that Syphon, the water of three other Syphons; ſo that all the water was of 4 Syphons, and conſequently quadruple to the firſt Syphon; but the quick height was onely double, and adding five Siphons, the quick height became triple, and with adding ſeven Syphons, the height increaſed quadruple; and ſo by adding of 9. it increaſed quintuple, and by adding of 11. it increaſed ſextuple, and by adding

ding of 13. it increaſed ſeptuple, and by adding of 15. octuple, and by adding of 17. nonuple, and laſtly by adding 19. Syphons; ſo that all the water was centuple to the water of one Syphon, yet nevertheleſs the quick height of all this water was onely decuple to the firſt height conjoyned by the water that iſſued from one onely Syphon.

For the more clear underſtanding of all which, I have made the following Figure; in which we have the mouth A, that maintaineth the water of the Veſſel B C in the ſame level; though it continually run; to the brim of the Veſſel are put 25. Syphons (and there may be many more) divided into 5 Claſſes, D E F G H, and the firſt D, are of one onely Syphon; the ſecond E, of three Syphons; the third F, of five; the fourth G, of 7; the fifth H, of 9; and one may ſuppoſe the ſixth of 11, the ſeventh of 13 Syphons, and ſo of the other Claſſes, all containing in conſequent odd numbers ſucceſſively (we are content to repreſent in the Figure no more but the five forenamed Claſſes to avoid confuſion) the gathered water D E F G H, which runneth thorow the Chanel I K L, and falleth into the out-let M N O P; and ſo much ſufficeth for the explanation of this experiment.



PROPOS. V. PROB. III.

Any River of any bigneſs, if being given to examine the quantity of the Water that runneth thorow the River in a time aſſigned.

BY what we have ſaid already in the two preceding Problems, we may alſo reſolve this that we have now before us; and it is done, by diverting in the firſt place from the great River a good big meaſurable Chanel, as is taught in the ſecond Probleme, and obſerving the abatement of the River, cauſed by the diverſion of the Chanel; and finding the proportion that the Water of the Chanel hath to that of the River, then let the Water of the Chanel be meaſured by the ſecond Probleme, and work as above, and you ſhall have your deſire.

CONSIDERATION. I.

AND although it ſeemeth as if it might prove difficult, and almoſt impoſſible to make uſe of the Regulator number, if one be about to meaſure the water of ſome great River, and conſequently would be impoſſible, or at leaſt very difficult to reduce the Theory of the firſt Probleme into practice: Yet nevertheleſs, I could ſay that ſuch great conceits of meaſuring the water of a great River, are not to come into the minds of any but great Perſonages, and potent Princes; of whom it is expected for their extraordinary concerns, that they will make theſe kinde of enquiries; as if here in *Italy* it ſhould be of the Rivers *Tyber*, *Velino*, *Chiana*, *Arno*, *Serchio*, *Adice*, in which it ſeemeth really difficult to apply the Regulator, to finde exactly the quick height of the River: But becauſe in ſuch like caſes ſometimes it would turn to account to be at ſome charge, to come to the exact and true knowledge of the quantity of water which that River carrieth, by knowledge whereof, other greater diſburſments might afterwards be avoided, that would oft times be made in vain; and prevent the diſguſts, which ſometimes happen amongſt Princes: Upon this ground I think it will be well to ſhew alſo the way how to make uſe of the Regulator in theſe great Rivers; in which if we will but open our eyes, we ſhall meet with good ones, and thoſe made without great coſt or labour, which will ſerve our turn.

For upon ſuch like Rivers there are Wears, or Lockes made,

to

to cauſe the Waters to riſe, and to turn them for the ſervice of Mills, or the like. Now in theſe Caſes it is ſufficient, that one erect upon the two extreames of the Weare two Pilaſters either of Wood or Brick, which with the bottome of the Weare do compoſe our Regulator, wherewith we may make our deſired operation, yea the Chanel it ſelf diverted ſhall ſerve, without making any other diverſion or union. And in brief, if the buſineſſes be but managed by a judicious perſon, there may wayes and helps be made uſe of, according to occaſion, of which it would be too tedious to ſpeak, and therefore this little that hath been hinted ſhall ſuffice.

CONSIDERATION II.

FRom what hath been declared, if it ſhall be well underſtood, may be deduced many benefits and conveniences, not onely in dividing of Running Waters for infinite uſes that they are put to in turning of Corne-Mills, Paper-Mills, Gins, Powder-Mills, Rice-Mills, Iron-Mills, Oil-Mills, Sawing-Mills, Mirtle-Mills, Felling-Mills, Fulling-Mills, Silk-Mills, and ſuch other Machines; but alſo in ordering Navigable Chanels, diverting Rivers and Chanels of Waters, or terminating and limiting the ſizes of Pipes for Fountains: In all which affairs there are great errours committed, to the loſſe of much expence, the Chanels and Pipes that are made, ſometimes not being ſufficient to carry the deſigned Waters, and ſometimes they are made bigger than is neceſſary; which diſorders ſhall be avoided, if the Engineer be adviſed of the things aboveſaid: and in caſe that to theſe Notions there be added the knowledge of Philoſophy and Mathematicks, agreeable to the ſublime Diſcoveries of *Signore Galilæo*, and the further improvement thereof by *Signore Evangeliſta Torricelli*, Mathematician to the Grand *Duke of Tuſcany*, who hath ſubtilly and admirably handled this whole buſineſſe of Motion, one ſhall then come to the knowledge of particular notions of great curioſity in the Theoricks, and of extraordinary benefit in the Practicks that daily occur in theſe buſineſſes.

And to ſhew, in effect, of what utility theſe Notions are, I have thought fit to inſert, in this place, the Conſiderations by me made upon the Lake of *Venice*, and to repreſent, at large, by the experience of the laſt year 1641. the moſt Serene *Erizzo*, then Duke of the ſaid Republique. Being therefore at *Venice*, in the year aforeſaid, I was requeſted by the moſt Illuſtrious and moſt Excellent *Signore Giovanni Baſa-*

donna

donna, a Senatour of great worth and merit, that I would ingenuously deliver my opinion touching the ſtate of the Lake of *Venice*; and after I had diſcourſed with his Honour ſeveral times, in the end I had order to ſet down the whole buſineſſe in writing, who having afterwards read it privately, the ſaid *Signore* imparted the ſame, with like privacy, to the moſt Serene PRINCE, and I received order to repreſent the ſame to the full *Colledge*, as accordingly I did in the Moneth of *May*, the ſame year, and it was as followeth.

CONSIDERATIONS
Concerning the
LAKE
OF
VENICE

BY

D. BENEDETTO CASTELLI,
Abbot of S. *Benedetto Aloyſio*, Mathematician to Pope *URBAN VIII.* and Profeſſor in ROME.

CONSIDERATION I.

THough the principal cauſe be but one onely, that in my judgment threatneth irreparable ruine to the Lake of *Venice*, in the preſent ſtate in which it now ſtands; Yet nevertheleſſe, I think that two Heads may be conſidered. And this Conſideration may peradventure ſerve us for to facilitate and explain the opportune remedies, though not to render the ſtate of things abſolutely unchangeable and eternal: an enterprize impoſſible, and eſpecially in that which having had ſome beginning, ought likewiſe neceſſarily to have its end; or at leaſt to prevent the danger for many hundreds of years; and poſſibly it may, in the mean time, by the mutation it ſelf be brought into a better condition.

I ſay therefore, that the preſent diſorder may be conſidered under two Heads; One is the very notable diſcovery of Land that is obſerved at the time of low Water, the which, beſides the obſtructing of Navigation in the Lake and alſo in the Chanels, doth likewiſe threaten another miſchief and diſorder worthy

worthy of very particular conſideration, which is, That the Sun drying up that mudde, eſpecially in the times of hot Summers, doth raiſe thence the putrified and pernicious vapours, fogs, and exhalations that infect the Air, and may render the City unhabitable.

The ſecond Head is the great Stoppage that daily is growing in the Ports, eſpecially of *Venice*, at *Malamoco*; concerning which matters I will hint certain general points, and then will proceed to the more particular and important affairs.

And firſt, I ſay, that I hold it altogether impoſſible to effect any thing, though never ſo profitable, which doth not bring with it ſome miſchief; and therefore the good and the hurt ought to be very well weighed, and then the leſſe harmful part to be imbraced.

Secondly, I propoſe to conſideration, that the ſo notable diſcovery of Earth & Mud, hath not been long obſerved, as I underſtand, from old perſons that can remember paſſages for fifty years paſt; which thing being true, as to me it ſeemeth moſt true, it ſhould appear that it could not but be good to reduce matters to that paſſe that they were at formerly, (laying aſide all affection or paſſion that ſelf-flattering minds have entertained for their own conceits) or at leaſt it ſhall be neceſſary ſpeedily to conſult the whole.

Thirdly, I hold that it is neceſſary to weigh, whether from the foreſaid diſcovery of Land, it followeth, that onely the Earth riſeth, as it is commonly thought by all, without diſpute; or whether the Waters are abated and faln away; or elſe whether it proceedeth from both the one and other cauſe. And here it would be ſeaſonable to enquire, what ſhare the ſaid cauſes may have, each conſidered apart in the foreſaid effect. For, in the firſt caſe, if the Earth have been raiſed, it would be neceſſary to conſider of taking it down, and removing it: But if the Waters have failed or abated, I believe that it would be extreamly neceſſary to reſtore and raiſe them: And if both theſe reaſons have conſpired in this effect, it will be neceſſary to remedy them each apart. And I do, for my part, think, that the ſo notable appearance of Shelves at the time of low Water, proceeds principally from the decreaſe and abatement of the Waters, which may confidently be affirmed to need no other proof, in regard that the *Brent* hath been actually diverted which did formerly diſcharge its Water into the Lake.

As to the other point of the great Stoppage of Ports, I hold, that all proceedeth from the violence of the Sea, which being ſometimes diſturbed by windes, eſpecially at the time of the waters flowing, doth continually raiſe from its bottome immenſe heaps

heaps of ſand, carrying them by the tide; and force of the waves into the Lake; it not having on its part any ſttength of current that may raiſe and carry them away, they ſink to the bottom, and ſo they choke up the Ports. And that this effect happeneth in this manner, we have moſt frequent experiences thereof along the Sea-coaſts: And I have obſerved in *Tuſcany* on the *Roman-ſhores*, and in the Kingdom of of *Naples*, that when a river falleth into the Sea, there is alwaies ſeen in the Sea it ſelf, at the place of the rivers out-let, the reſemblance, as it were, of an half-Moon, or a great ſhelf of ſettled ſand under water, much higher then the reſt of the ſhore, and it is called in *Tuſcany*, *il Cavallo*; and here in *Venice*, *lo Scanto*: the which cometh to be cut by the current of the river, one while on the right ſide, another while on the left, and ſometimes in the midſt, according as the Wind ſits. And a like effect I have obſerved in certain little Rillets of water, along the Lake of *Bolſena*; with no other difference, ſave that of ſmall and great.

Now whoſo well conſidereth this effect, plainly ſeeth that it proceeds from no other, than from the contrariety of the ſtream of the River, to the *impetus* of the Sea-waves; ſeeing that great abundance of ſand which the Sea continually throws upon the ſhore, cometh to be driven into the Sea by the ſtream of the river; and in that place where thoſe two impediments meet with equal force, the ſand ſetleth under water, and thereupon is made that ſame Shelf or *Cavallo*; the which if the river carry water, and that any conſiderable ſtore, it ſhall be thereby cut and broken; one while in one place, and another while in another; as hath been ſaid, according as the Wind blows: And through that Chanel it is that Veſſels fall down into the Sea, and again make to the river, as into a Port. But if the Water of the river ſhall not be continual or ſhall be weak, in that caſe the force of the Sea-Wind ſhall drive ſuch a quantity of ſand into the mouth of the Port, and of the river, as ſhall wholly choak it up. And hereupon there are ſeen along the Sea-ſide, very many Lakes and Meers, which at certain times of the year abound with waters, and the Lakes bear down that encloſure, and run into the Sea.

Now it is neceſſary to make the like reflections on our Ports of *Venice*, *Malamocco*, *Bondolo*, and *Chiozza*; which in a certain ſenſe are no other than Creeks, mouths, and openings of the ſhore that parts the Lake from the main Sea; and therefore I hold that if the Waters in the Lake were plentiful, they would have ſtrength to ſcowr the mouths of the Ports thorowly, & with great force; but the Water in the Lake failing, the Sea will without any oppoſal, bring ſuch a drift of ſand into the Ports; that it

it doth not wholly choke them up, it ſhall render them at leaſt unprofitable, and impoſſible for Barks and great Veſſels.

Many other conſiderations might be propounded concerning theſe two heads of the ſtoppage of the Ports, and of the appearance of the Ouze and Mud in the Lakes; but ſo much ſhall ſuffice us to have hinted, to make way for diſcourſing of the operations about the oportune remedies.

Yet before that I propound my opinion, I ſay, That I know very well that my propoſal, at firſt ſight, will ſeem abſurd and inconvenient; and therefore, as ſuch, will perhaps be rejected by the moſt: and ſo much the rather, for that it will prove directly contrary to what hath hitherto been, and as I hear, is intended to be done: And I am not ſo wedded to my opinions, but that I do conſider what others may judge thereof: But be it as it will, I am obliged to ſpeak my thoughts freely, and that being done, I will leave it to wiſer men than my ſelf, when they ſhall have well conſidered my reaſons, to judge and deliberate of the *quid agendum*: And if the ſentence ſhall go againſt me, I appeal to the moſt equitable and inexorable Tribunal of Nature, who not caring in the leaſt to pleaſe either one party or another, will be alwaies a punctual and inviolable executrix of her eternal Decrees, againſt which neither humane deliberations, nor our vain deſires, ſhall ever have power to rebell. I added by word of mouth that which followeth.

Though your Highneſs intereſt your ſelf in this Noble Colledge, and cauſe it to be confirmed in the * Senate by univerſal Vote, that the Winds do not blow, that the Sea doth not fluctuate, that the Rivers do not run; yet ſhall the Winds be alwaies deaf, the Sea ſhall be conſtant in its inconſtancy, and the Rivers moſt obſtinate: And theſe ſhall be my Judges, and to their determination I refer my ſelf.

* In *Pregadi*, a particular Council, the Senators of which have great Authority.

By what hath been ſaid, in my opinion, that is made very clear and manifeſt, which in the beginning of this diſcourſe I glanced at; namely, That the whole diſorder, although it be divided into two heads, into the diſcovery of the Mud, and of the ſtoppage Ports, yet nevertheleſs, by the application of one onely remedy, and that in my eſteem very eaſie, the whole ſhall be removed: And this it is; That there be reſtored into the Lake as much Water as can be poſſible, and in particular from the upper parts of *Venice*, taking care that the Water be as free from Mud as is poſſible. And that this is the true and real remedy of the precedent diſorders, is manifeſt: For in the paſſage that this Water ſhall make thorow the Lakes, it ſhall of it ſelf by degrees clear the Chanels in ſundry parts of them, according to the currents that it ſhall ſucceſſively acquire, and in this manner being diſ-

perſed

perſed thorow the Lake, it ſhall maintain the waters in the ſame, and in the Chanels much higher, as I ſhall prove hereafter; a thing that will make Navigation commodious; and that, which moreover is of great moment in our buſineſſe; thoſe Shelves of Mud which now diſcover themſelves at the time of Low-Waters ſhall be alwayes covered, ſo that the putrefaction of the Air ſhall alſo be remedied.

And laſtly, this abundance of Water being alwayes to diſcharge it ſelf into the Sea by the Ports, I do not doubt, but that their bottomes will be ſcoured. And that theſe effects muſt follow, Nature her ſelf ſeemeth to perſwade, there remaining onely one great doubt, whether that abundance of Water that ſhall be brought into the Lake may be really ſufficient to make the Waters riſe ſo much as to keep the Shelves covered, and to facilitate Navigation, which ought to be at leaſt half a * Brace, or thereabouts. And indeed it ſeemeth at firſt ſight to be impoſſible, that the ſole Water of the * *Brent* let into the Lake, and diſperſed over the ſame, can occaſion ſo notable an height of water; and the more to confirm the difficulties, one might ſay, reducing the reaſon to calculation, that in caſe the *Brent* were 40. Braces broad, and two and an half high, and the breadth of the Lake were 20000. Braces, it would ſeem neceſſary that the height of the water of the *Brent* dilated and diſtended thorow the Lake would be but onely $\frac{1}{5000}$ of a Brace in height, which is imperceptible, and would be of no avail to our purpoſe; nay more, it being very certain that the *Brent* runneth very muddy and foul, this would occaſion very great miſchief, filling and contracting the Lake, and for that reaſon this remedy ought, as pernicious, to be totally excluded and condemned.

* A *Venice* Brace is $\frac{11}{12}$ of our yard.

* A River of that name.

I here confeſſe that I am ſurprized at the forme of the Argument, as if I were in a certain manner convinced, that I dare not adventure to ſay more, or open my mouth in this matter; but the ſtrength it ſelf of the Argument, as being founded upon the means of Geometrical and Arithmetical Calculation, hath opened me the way to diſcover a very crafty fraud that is couched in the ſame Argument, which fraud I will make out to any one that hath but any inſight in *Geometry* and *Arithmetick*. And as it is impoſſible, that ſuch an argument ſhould be produced by any but ſuch as have taſted of theſe, in ſuch affairs, moſt profitable, and moſt neceſſary Sciences; ſo do not I pretend to make my ſelf underſtood, ſave onely by ſuch, to whom I will evince ſo clearly, as that more it cannot be deſired, the errour and fraud wherein thoſe Ancients and Moderns have been, and alwayes are intangled, that have in any way yet handled this matter of conſidering the Meaſure and Quantity of the Waters that move.

And ſo great is the eſteem that I have for that which I am now about to ſay touching this particular, that I am content that all the reſt of my Diſcourſe be rejected; provided, that that be perfectly underſtood, which I am hereafter to propoſe, I holding and knowing it to be a main Principle, upon which all that is founded that can be ſaid either well or handſomely on this particular. The other Diſcourſes may have an appearance of being probable, but this hits the mark as full as can be deſired, arriving at the higheſt degree of certainty.

I have, ſeventeen years ſince, as I repreſented to the moſt Serene Prince, and to the Right Honourable the Preſident of the Lords the Commiſſioners of the *Sewers, written a Treatiſe of the Meaſure of the waters that move, in which I Geometrically demonſtrate and declare this buſineſſe, and they who ſhall have well underſtood the ground of my Diſcourſe, will reſt fully ſatisfied with that which I am now about to propoſe: But that all may become rhe more eaſie, I will more briefly explicate and declare ſo much thereof as I have demonſtrated in the Diſcourſe, which will ſuffice for our purpoſe: And if that ſhould not be enough, we have alwayes the experiment of a very eaſie and cheap way to clear up the whole buſineſſe. And moreover I will take the boldneſſe to affirm, that in caſe there ſhould not for the preſent any deliberation be made concerning this affair, according to my opinion; yet nevertheleſſe it will be, at ſome time or other; or if it be not, things will grow worſe and worſe.

* *I. Savii dell' Acque*, a particular Council that take care of the Lakes and other Aquatick affairs.

For more clear underſtanding, therefore, it ought to be known, that it being required, as it is generally uſed, to meaſure the waters of a River, its breadth and its depth is taken, and theſe two dimenſions being multiplied together, the product is affirmed to be the quantity of that River: As for example, if a River ſhall be 100. feet broad, and 20. feet high, it will be ſaid, that that River is 2000 feet of Water, and ſo if a Ditch ſhall be 15. feet broad, and 5. feet high, this ſame Ditch will be affirmed to be 75. feet of Water: And this manner of meaſuring Running Water hath been uſed by the Ancients, and by Moderns, with no other difference, ſave onely that ſome have made uſe of the Foot, others of the Palme, others of the Brace, and others of other meaſures.

Now becauſe that in obſerving theſe Waters that move, I frequently found, that the ſame Water of the ſame River was in ſome ſites of its Chanel pretty big, and in others much leſſe, not arriving in ſome places to the twentieth, nor to the hundreth part of that which it is ſeen to be in other places; therefore this vulgar way of meaſuring the Waters that move, for that they did

not

not give me a certain and ſtable meaſure and quantity of Water, began deſervedly to be ſuſpected by me, as difficult and defective, being alwayes various, and the meaſure, on the contrary, being to be alwayes determinate, and the ſame; it is therefore written, that *Pondus & Pondus, Menſura & Menſura, utrumque abominabile eſt apud Deum*, Exod. I conſidered that in the Territory of *Breſcia*, my native Countrey, and in other places, where Waters are divided to overflow the Grounds, by the like way of meaſuring them, there were committed grievous and moſt important errours, to the great prejudice of the Publique and of Private perſons, neither they that ſell, nor they that buy underſtanding the true quantity of that which is ſold and bought: In regard that the ſame ſquare meaſure, as is accuſtomed in thoſe parts, aſſigned one particular perſon, carried to ſometimes above twice or thrice as much water, as did the ſame ſquare meaſure aſſigned to another. Which thing proveth to be the ſame inconvenience, as if the meaſure wherewith Wine and Oil is bought and ſold, ſhould hold twice or thrice as much Wine or Oil at one time as at another. Now this Conſideration invited my minde and curioſity to the finding out of the true meaſure of Running Waters. And in the end, by occaſion of a moſt important buſineſſe that I was imployed in ſome years ſince, with great intenſeneſſe of minde, and with the ſure direction of *Geometry*, I have diſcovered the miſtake, which was, that we being upon the buſineſſe of taking the meaſure of the Waters that move, do make uſe of two dimenſions onely, namely, breadth and depth, keeping no account of the length. And yet the Water being, though running, a Body, it is neceſſary in forming a conceit of its quantity, in relation to another, to keep account of all the three Dimenſions, that is of length, breadth, and depth.

Here an objection hath been put to me, in behalf of the ordinary way of meaſuring Running Waters, in oppoſition to what I have above conſidered and propoſed: and I was told, Its true, that in meaſuring a Body that ſtands ſtill, one ought to take all the three Dimenſions; but in meaſuring a Body that continually moveth, as the Water, the caſe is not the ſame: For the length is not to be had, the length of the water that moveth being infinite, as never finiſhing its running; and conſequently is incomprehenſible by humane underſtanding, and therefore with reaſon, nay upon neceſſity it cometh to be omitted.

In anſwer to this, I ſay, that in the aboveſaid Diſcourſe, two things are to be conſidered diſtinctly; Firſt, whether it be poſſible to frame any conceit of the quantity of the Body of the Water with two Dimenſions onely. And ſecondly, whether this length be to be found. As to the firſt, I am very certain that no man, let

him

him be never ſo great a Wit, can never promiſe to frame a conceit of the quantity of the Body of Water, without the third Dimenſion of length: and hereupon I return to affirm, that the vulgar Rule of meaſuring Running water is vain and erroneous. This point being agreed on, I come to the ſecond, which is, Whether the third Dimenſion of length may be meaſured. And I ſay, that if one would know the whole length of the water of a Fountain or River, thereby to come to know the quantity of all the Water, it would prove an impoſſible enterprize, nay the knowing of it would not be uſeful. But if one would know how much water a Fountain, or a River carrieth in a determinate time of an hour, of a day, or of a moneth, &c. I ſay, that it is a very poſſible and profitable enquiry, by reaſon of the innumerable benefits that may be derived thence, it much importing to know how much Water a Chanel carrieth in a time given; and I have demonſtrated the ſame above in the beginning of this Book; and of this we ſtand in need in the buſineſſe of the Lake, that ſo we may be able to determine how much ſhall be the height of the *Brent*, when it is ſpread all over the Lake: For the three dimenſions of a Body being given, the Body is known; and the quantity of a Body being given, if you have but two dimenſions, the third ſhall be known. And thus diving farther and farther into this Conſideration, I found that the Velocity of the courſe of the water may be an hundred times greater or leſſer in one part of its Chanel than in another. And therefore although there ſhould be two mouths of Waters equal in bigneſſe; yet nevertheleſs it might come to paſſe, that one might diſcharge an hundred or a thouſand times more water than another: and this would be, if the water in one of the mouths ſhould run with an hundred or a thouſand times greater velocity, than the other; for that it would be the ſame as to ſay, that the ſwifter was an hundred or a thouſand times longer, than the ſlower: and in this manner I diſcovered that to keep account of the velocity, was the keeping account of the Length.

And therefore it is manifeſt, that when two Mouths diſcharge the ſame quantity of Water in an equal velocity, it is neceſſary that the leſs ſwift Mouth be ſo much bigger than the more ſwift; as the more ſwift exceedeth in velocity the leſs ſwift; as for example.

In caſe two Rivers ſhould carry equal quantity of water in equal times, but that one of them ſhould be four times more ſwift than the other, the more ſlow ſhould of neceſſity be four times more large. And becauſe the ſame River in any part thereof alwaies diſchargeth the ſame quantity of Water in equal times (as is demonſtrated in the firſt Propoſition of the firſt

Book

Book* of the measure of Running Watets;) but yet doth not run thorowout with the same velocity: Hence it is, that the vulgar measures of the said River, in divers parts of its Chanel, are alwaies divers; insomuch, that if a River passing through its chanel had such velocity, that it ran 100 Braces in the $\frac{1}{2}$. of an hour, and afterwards the said River should be reduced to so much tardity of motion, as that in the same time it should not run more than one Brace, it would be necessary that that same River should become 100. times bigger in that place where it was retarded; I mean, 100. times bigger than it was in the place where it was swifter. And let it be kept well in mind, that this point rightly understood, will clear the understanding to discover very many accidents worthy to be known. But for this time let it suffice, that we have onely declared that which makes for our purpose, referring apprehensive and studious Wits to the perusal of my aforenamed Treatise; for therein he shall finde profit and delight both together.

* He here intends the Demonstrations following, at the end of the first Book

Now applying all to our principal intent, I say, That by what hath been declared it is manifest, that if the *Brent* were 48. Braces broad, and $2\frac{1}{2}$ high, in some one part of its Chanel, that afterwards the same Water of the *Brent* falling into the Lake, and passing thorow the same to the Sea, it should lose so much of its velocity, that it should run but one Brace, in the time wherein whilst it was in its Chanel at the place aforesaid, it ran 100. Braces. It would be absolutely necessary, that increasing in measure, it should become an hundred times * thicker; and therefore if we should suppose that the Lake were 20000. Braces, the *Brent* that already hath been supposed in its Chanel 1001 Braces, being brought into the Lake, should be 100. times 100. Braces; that is, shall be 10000. Braces in thickness, and consequently shall be in height half a Brace; that is, $\frac{1}{200}$ of a Brace, and not $\frac{1}{2}$. of a Brace, as was concluded in the Argument.

* Deeper.

Now one may see into what a grois errour of 99. in 100. one may fall through the not well understanding the true quantity of Running Water, which being well understood, doth open a direct way to our judging aright in this most considerable affair.

And therefore admitting that wich hath been demonstrated, I say, that I would (if it did concern me) greatly encline to consult upon the returning of the *Brent* again into the Lake: For it being most evident, that the *Brent* in the Chanel of its mouth, is much swifter than the *Brent* being brought into the Lake, it will certainly follow thereupon, that the thickness of the Water of *Brent* in the Lake, shall be so much greater than that of *Brent* in *Brent*, by how much the *Brent* in *Brent* is swifter than the *Brent* in the Lake.

1. From which operation doth follow in the first place, that the Lake being filled and increased by these Waters, shall be more Navigable, and passible, than at present we see it to be.

2. By the current of these Waters, the Chanels will be scoured, and will be kept clean from time to time.

3. There will not appear at the times of low-waters so many Shelves, and such heaps of Mud, as do now appear.

4. The Ayr will become more wholesom, for that it shall not be so infected by putrid vapours exhaled by the Sun, so long as the Miery Ouze shall be covered by the Waters.

5. Lastly, in the current of these advantagious Waters,, which must issue out of the Lake into the Sea, besides those of the Tyde, the Ports will be kept scoured, and clear: And this is as much as I shall offer for the present, touching this weighty business; alwaies submitting my self to sounder judgements.

Of the above-said Writing I presented a Copy at *Venice*, at a full Colledge, in which I read it all, and it was hearkned to with very great attention; and at last I presented it to the Duke, and left some Copies thereof with sundry Senators, and went my way, promising with all intenseness to apply my pains with reiterated studies in the publick service; and if any other things should come into my minde, I promised to declare them sincerely, and so took leave of *His Serenity*, and that Noble Council. When I was returned to *Rome*, this business night and day continually running in my mind, I hapned to think of another admirable and most important conceit, which with effectual reasons, confirmed by exact operations, I with the Divine assistance, made clear and manifest; and though the thing at first sight seemed to me a most extravagant Paradox, yet notwithstanding, having satisfied my self of the whole business, I sent it in writing to the most Illustrious and most Noble *Signore Gio. Basadonna*; who after he had well considered my Paper, carried it to the Council; and after that those Lords had for many months maturely considered thereon, they in the end resolved to suspend the execution of the diversion which they had before consulted to make of the River *Sile*, and of four other Rivers, which also fall into the Lake; a thing by me blamed in this second Paper, as most prejudicial, and harmful. The writing spake as followeth.

CONSIDERATIONS
Concerning the
LAKE
OF
VENICE.

PART II.

IF the diſcourſing well about the truth of things, Moſt Serene Prince, were as the carrying of Burdens, in which we ſee that an hundred Horſes carry a greater weight than one Horſe onely; it would ſeem that one might make more account of the opinion of many men, than of one alone; But becauſe that diſcourſing more reſembleth running, than carrying Burdens, in which we ſee that one Barb alone runneth faſter than an hundred heavy-heel'd Jades; therefore I have ever more eſteemed one Concluſion well managed, and well conſidered by one underſtanding man, although alone, than the common and Vulgar opinions; eſpecially, when they concern abſtruce and arduous points: Nay in ſuch caſes the opinions moulded and framed by the moſt ignorant and ſtupid Vulgar, have been ever ſuſpected by me as falſe, for that it would be a great wonder if in difficult matters a common capacity ſhould hit upon that which is handſom, good, and true. Hence I have, and do hold in very great veneration the ſumme of the Government of the moſt Serene, and eternal Republick of *Venice*; which although, as being in nature a Common-wealth, it ought to be governed by the greater part; yet nevertheleſs, in arduous affairs, it is alwaies directed by the Grave Judgement of few, and not judged blindly

by the *Plebeian* Rout. Tis true, that he that propoundeth Propoſitions far above the reach of common capacity, runneth a great hazard of being very often condemned without further Proceſs, or knowledge of the Cauſe; but yet for all that, the truth is not to be deſerted in moſt weighty affairs, but ought rather to be explained in due place and time with all poſſible perſpicuity; that ſo being well underſtood, and conſidered, it may come afterwards for the Common good to be embraced.

This which I ſpeak in general, hath often been my fortune in very many particulars, not onely when I have kept within the bounds of meer ſpeculation, but alſo when I have chanced to deſcend to Practice, and to Operations: and your Highneſs knoweth very well what befel me the laſt Summer 1641. when in obedience to your Soveraign Command, I did in full Colledge repreſent my thoughts touching the ſtate of the Lake of *Venice*; for there not being ſuch wanting, who without ſo much as vouchſafing to underſtand me, but having onely had an inkling, and bad apprehenſion of my opinion, fell furiouſly upon me, and by violent means both with the Pen and Preſs, full of Gall, did abuſe me in reward of the readineſs that I had expreſt to obey and ſerve them: But I was above meaſure encouraged and pleaſed, to ſee that thoſe few who vouchſafed to hear me, were all either thorowly perſwaded that my opinion was well grounded, or at leaſt ſuſpended their prudent verdict to more mature deliberation. And though at the firſt bout I chanced to propoſe a thing that was totally contrary to the moſt received and antiquated opinion, and to the reſolutions and conſultations taken above an hundred years ago: Moved by theſe things, and to ſatisfie alſo to the promiſe that I had made of tendering unto them what ſhould farther offer it ſelf unto me touching the ſame buſineſs; I have reſolved to preſent to the Throne of your Highneſs, another Conſideration of no leſs importance, which perhaps at firſt ſight will appear a ſtranger Paradox; but yet brought to the Teſt and Touch-ſtone of experience, it ſhall prove moſt clear and evident. If it ſhall be accounted of, ſo that it ſucceedeth to the benefit of your Highneſs, I ſhall have obtained my deſire and intent: And if not, I ſhall have ſatisfied my ſelf, and ſhall not have been wanting to the Obligation of your moſt faithful Servant, and native ſubject.

That which I propounded in the Mouths paſs, touching the moſt important buſineſs of the Lake, though it did onely expreſly concern the point of the diverſion of the Mouth of the Lake, already made and put in execution; yet it may be underſtood and applyed alſo to the diverſion under debate, to be made of the other five Rivers, and of the *Sile* in particular.

Now

Now touching this, I had the fortune to offer an admirable accident that we meet with when we come to the effect, which I verily believe will be an utter ruine to the Lake of *Venice.*

I ſay therefore, that by diverting theſe five Rivers that remain, although their water that they diſcharge for the preſent into the Lake is not all taken together ⅘ parts of what the *Brent* alone did carry, yet nevertheleſſe the abatement of the water of the Lake which ſhall enſue upon this laſt diverſion of four parts, which was the whole water, ſhall prove double to that which hath happened by the diverſion of *Brent* onely, although that the *Brent* alone carried five parts of that water, of which the Rivers that are to be diverted carry four: A wonder really great, and altogether unlikely; for the reducing all this Propoſition to be underſtood, is as if we ſhould ſay, that there being given us three Rivers, of which the firſt diſchargeth five parts, the ſecond three, and the third one, and that from the diverſion of the firſt, there did follow ſuch a certain abatement or fall; from the taking away of the ſecond there ought to follow alſo ſo much more abatement; And laſtly, from the withdrawing of the third the water ought to fall ſo much more, which is wholly impoſſible: And yet it is moſt certain, and beſides the demonſtration that perſwades me to it, which I ſhall explain in due time, I can ſet before your eyes ſuch an experiment as is not to be denied by any one, although obſtinate: and I will make it plainly ſeen and felt, that by taking away only four parts of the five, which ſhall have been taken away, the abatement proveth double to the abatement enſuing upon the diverting firſt of the five onely; which thing being true, as moſt certainly it is, it will give us to underſtand how pernicious this diverſion of five Rivers is like to prove, if it ſhall be put in execution.

By this little that I have hinted, and the much that I could ſay, let your Highneſſe gather with what circumſpection this buſineſſe ought to be managed, and with how great skill he ought to be furniſhed who would behave himſelf well in theſe difficult affairs.

I have not at this time explained the demonſtration, nor have I ſo much as propounded the way to make the Experiment, that I am able to make in confirmation of what I have ſaid, that ſo by ſome one or others miſ-apprehending the Demonſtration, and maiming the Experiment, the truth may not happen to ſhine with leſſe clarity than it doth, when all miſts of difficulty are removed: and if ſo be, no account ſhould be made of the Reaſons by me alledged, and that men ſhould ſhut their eyes againſt the Experiments that without coſt or charge may be made, I do de-

clare and proteſt that there ſhall follow very great dammages to the Fields of the main Land, and extraordinary ſummes ſhall be expended to no purpoſe. The Lake undoubtedly will become almoſt dry, and will prove impaſſible for Navigation, with a manifeſt danger of corrupting the Air: And in the laſt place there will unavoidably enſue the choaking and ſtoppage of the Ports of *Venice*.

Upon the 20th. of *December*, 1641. I imparted this my ſecond Conſideration to the moſt Excellent *Signore Baſadonna*, preſenting him with a Copy thereof amongſt other Writings, which I have thought good to inſert, although they ſeem not to belong directly to our buſineſſe of the Lake.

The way to examine the MUD and SAND that entereth and remaineth in the LAKE of *VENICE*.

To the moſt Excellent SIGNORE GIO. BASADONNA.

TWo very conſiderable Objections have been made againſt my opinion concerning the Lake of *Venice*: One was that, of which I have ſpoken at large in my firſt Conſideration, namely, that the *Brents* having been taken out of the Lake, cannot have been the occaſion of the notable fall of the Waters in the Lake, as I pretend, and conſequently, that the turning *Brent* into the Lake would be no conſiderable remedy, in regard that the water of *Brent*, and the great expanſion of the Lake over which the water of *Brent* is to diffuſe and ſpread being conſidered, it is found that the riſe proveth inſenſible.

The ſecond Objection was, that the *Brent* is very muddy, and therefore if it ſhould fall muddy into the Lake, the Sand would ſink and fill up the ſame.

Touching the firſt Query, enough hath been ſaid in my firſt Conſideration, where I have plainly diſcovered the deceipt of the Argument, and ſhewn its fallacy; It remaineth now to examine the

the ſecond : to which in the firſt place I ſay, that one of the firſt things that I propoſed in this affair was, that I held it impoſſible to do any act, though never ſo beneficial, that was not alſo accompanied by ſome inconvenience and miſchief; and therefore we are to conſider well the profit, and the loſſe and prejudice; and they both being weighed, we ſhall be able to chooſe the leſſer evil: Secondly, I admit it to be moſt true, that *Brent* is at ſome times muddy, but it is alſo true, that for the greater part of the year it is not muddy. Thirdly, I do not ſee nor underſtand what ſtrength this objection hath, being taken ſo at large, and in general; and methinks that it is not enough to ſay, that the *Brent* runneth muddy, and to aſſert that it depoſeth its Muddineſſe in the Lake, but we ought moreover to proceed to particulars, and ſhew how much this Mud is, and in what time this choaking up of the Ports may be effected. For the Reaſons are but too apparent and particular, that conclude the ruine of the Lake, and that in a very ſhort time, (for mention is made of dayes) the Waters diverſion being made, and moreover we have the circumſtance of an Experiment, the ſtate of things being obſerved to have grown worſe ſince the ſaid diverſion. And I have demonſtrated, that in caſe the Diverſion of the *Sile* and the other Rivers ſhould be put in execution, the Lake would in a few dayes become almoſt dry; and the Ports would be loſt, with other miſchievous conſequences. But on the other ſide, although that we did grant the choaking of them, we may very probably ſay, that it will not happen, ſave onely in the ſucceſſion of many and many Centuries of years. Nor can I think it prudent counſel to take a reſolution and imbrace a Deſigne now, to obtain a benefit very uncertain, and more than that, which only ſhall concern thoſe who are to come very many Ages after us, and thereby bring a certain inconvenience upon our ſelves, and upon our children that are now alive and preſent.

Let it be alledged therefore, (although I hold it falſe) that by the diverſions of the Rivers the Lake may be kept in good condition for ſeveral years to come.

But I ſay confidently, and hope to demonſtrate it; That the Diverſions will bring the Lake, even in our dayes, to be almoſt dry, and at leaſt will leave ſo little water in it, that it ſhall ceaſe to be Navigable, and the Ports ſhall moſt infallibly be choaked up. I will therefore lay upon experience, in anſwer to this Objection, that it is very neceſſary firſt well to diſcourſe, and rationally to particularize and aſcertain the beſt that may be this point of the quantity of this ſinking Mud or Sand.

Now I fear I ſhall make my ſelf ridiculous to thoſe, who meaſuring the things of Nature with the ſhallowneſſe of their brains

do

do think that it is absolutely impossible to make this enquiry, and will say unto me, *Quis mensus est pugillo aquas, & terram palmo ponderavit* ? Yet nevertheless I will propound a way whereby, at least in gross, one may find out the same.

Take a Vessel of Cylindrical Figure, holding two barrels of water, or thereabouts ; and then fill it with the water of *Brent*, at its Mouth or Fall into the Lake ; but in the Lake at the time that the *Brent* runneth muddy, and after it hath begun to run muddy for eight or ten hours, to give the mud time to go as far as S. *Nicolo*, to issue into the Sea ; and at the same time take another Vessel, like, and equal to the first, and fill it with the water of the Lake towards S. *Nicolo*, (but take notice that this operation ought to be made at the time when the waters go out, and when the Sea is calm) and then, when the waters shall have setled in the aforesaid Vessels, take out the clear water, and consider the quantity of Sand that remains behind, and let it be set down, or kept in mind : And I am easily induced to think, that that shall be a greater quantity of Sand which shall be left in the first Vessel, than that left in the second Vessel. Afterwards when the *Brent* shall come to be clear, let both the operations be repeated, and observe the quantity of Sand in the aforesaid Vessels ; for if the Sand in the first Vessel should be most, it would be a sign, that in the revolution of a year the *Brent* would depose Sand in the Lake : And in this manner one may calculate to a small matter what proportion the Sand that entreth into the Lake, hath to that which remains : And by that proportion one may judge how expedient it shall be for publick benefit. And if at several times of the year you carefully repeat the same operations, or rather observations, you would come to a more exact knowledge in this business : And it would be good to make the said operations at those times, when the Lake is disturbed by strong high Winds, and made muddy by its own Mud, raised by the commotion of the Waters.

This notion would give us great light, if the same observations should be made towards the Mouth of *Lio*, at such time as the waters flow and ebb, in calm seasons ; for so one should come to know whether the waters of the Lake are more thick at the going out, than at the entrance. I have propounded the foregoing way of measuring Sands and Mud, to shew that we are not so generally, and inconsiderately to pronounce any sentence, but proceed to stricter inquiries, and then deliberate what shall be most expedient to be done. Others may propose more exquisite examinations, but this shall serve me for the present.

I will add onely, that if any one had greater curiosity (it would be profitable to have it) in investigating more exactly the quantity

tity of the Water that entereth into the Lake, by the means that I have ſhewen in the beginning of this Book: When he ſhall have found the proportion of the quantity of water to the quantity of Sand or Mud, he ſhall come to know how much Sand the *Brent* ſhall leave in the Lake in the ſpace of a year. But to perform theſe things, there are required perſons of diſcretion, and fidelity, and that are imployed by publick Order; for there would thence reſult eminent benefit and profit.

Here are wanting LETTERS *from ſeveral perſons.*

To the Reverend Father, *Franceſco di* S. GIUSEPPE.

IN execution of the command that you laid upon me in your former Letters, by order from the moſt Serene, my Lord, *Prince Leopold*; that I ſhould ſpeak my judgement concerning the diſimboguement of the River called *Fiume morto*, whether it ought to be let into the Sea, or into *Serchio*; I ſay, that I chanced 18. years ſince to be preſent, when the ſaid Mouth was opened into the Sea, and that of *Serchio* ſtopt; which work was done to remedy the great Innundation that was made in all that Country, and Plain of *Piſa*, that lyeth between the River *Arno*, and the Mountains of *S. Giuliano*, and the River *Serchio*; which Plain continued long under water, inſomuch that not onely in the Winter, but alſo for a great part of the Summer, thoſe fields were overflowed; and when that the Mouth of *Fiume morto* was effectually opened into the Sea, the place was preſently freed from the waters. and drained, to the great ſatisfaction of the Owners of thoſe Grounds. And here I judge it worth your notice, that for the generality of thoſe that poſſeſs eſtates in thoſe parts, they deſired that the Mouth of *Fiume morto* might ſtand open to the Sea, and thoſe who would have it open into *Serchio*, are perſons that have no other concernment there, ſave the hopes of gaining by having the diſpoſe of Commiſſions, and the like, &c,

But for the more plain underſtanding of that which is to be ſaid, it muſt be known, That the reſolution of opening the ſaid Mouth into *Serchio*, was taken in the time of the Great Duke *Ferdinando* the firſt, upon the ſame motives that are at this time again propoſed, as your Letters tell me, Since that, it manifeſtly appearing, that *Fiume morto* had, and hath its Mouth open to the Sea, the Plain hathbeen kept dry; and it being alſo true, that

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the fury of the South, and South-West-Winds carryed such abundance of sand into the Mouth, or Out-let of *Fiume morto*, that it wholly stopt it up: especially when the waters on *Pisa* side were low and shallow, And they think, that turning the Lake of *Fiume morto* into *Serchio*, and the *Serchio* maintaining continually its own Mouth with the force of its waters open to the Sea, and consequently also *Fiume morto*, they would have had the Out-let clear and open; and in this manner they think, that the Plain of *Pisa* would have been freed from the waters. The busines passeth for current, at first sight; but experience proveth the contrary, and Reason confirmeth the same: For the height of the water of those Plains, was regulated by the height of the waters in the Mouth of *Fiume morto*; that is, The waters at the Mouth being high, the waters also do rise in the fields; and when the waters at the Mouth are low, the waters of the fields do likewise abate: Nor is it enough to say, That the Out-let or Vent of *Fiume morto* is continual, but it must be very low: Now if *Fiume morto* did determine in *Serchio*, it is manifest that it would determine high; for *Serchio* terminating in the Sea, when ever it more and more aboundeth with water, and riseth, it is necessary that also *Fiume morto* hath its level higher, and consequently shall keep the waters in the Plains higher. Nay, it hath happened sometimes (and I speak it upon my own sight) that *Fiume morto* hath reversed its course upwards towards *Pisa*; which case will ever happen, whensoever the *Pisan* waters chance to be lower than the level of those of *Serchio*; for in that case the waters of *Serchio* return back upon the Plains thorow *Fiume morto* in such sort, that the Muddinesses, and the *Serchio* have been observed to be carried by this return as farr as the Walls of *Pisa*; and then before such time as so great waters can be asswaged, which come in with great fury, and go out by little and little, there do pass very many days, and moneths, nay sometimes one being never able to find the waters of *Serchio*, when at the shalloweſt, so low as the Sea in level; (which is the lowest place of the waters) it thence doth follow, that the waters of *Fiume morto* should never at any time of the year, so long as they determine in *Serchio*, be so low, as they come to be when the same *Fiume morto* determineth in the Sea. Tis true indeed, that the Mouth of *Fiume morto*, opened into the Sea, is subject to the inconvenience of being stopt up by the force of Winds: But in this case, it is necessary to take some pains in opening it; which may easily be done, by cutting that Sand a little which stayeth in the Mouth, after that the Wind is laid; and it is enough if you make a Trench little more than two Palms in breadth; for the water once beginning to run into it, it will in a few hours carry

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that Sand away with it, and there will enſue a deep and broad Trench that will drain away all the water of the Plains in very little time. And I have found by practice, that there having been a great quantity of Sand driven back, by the fury of the South-Weſt-Wind, into the Mouth of *Fiume morto*, I having cauſed the little gutter to be made in the Morning, ſomewhat before Noon, a Mouth hath been opened of 40. Braces wide, and notably deep, inſomuch that the water, which before had incommoded all the Champian ran away in leſs than three dayes, and left the Country free and dry, to the admiration of all men. There was preſent upon the place, at this buſineſs, on the ſame day that I opened the Mouth, the moſt Serene great Duke, the moſt Serene Arch-Dutcheſs Mother, all the Commiſſioners of Sewers, with many other Perſons and Peaſants of thoſe parts; and they all ſaw very well, that it was never poſſible that a little Bark of eight Oars, which was come from *Legorn* to wait upon the great Duke, ſhould ever be able to maſter the Current, and to make up into *Fiume morto*; and his Highneſs, who came with an intent to cauſe the ſaid Mouth towards the Sea to be ſtopt; and that into *Serchio* to be opened, changed his judgement, giving order that it ſhould be left open towards the Sea, as it was done. And if at this day it ſhall return into *Serchio*, I am very certain that it will be neceſſary to open it again into the Sea. And there was alſo charge and order given to a perſon appointed for the purpoſe, that he ſhould take care to open the ſaid Mouth, as hath been ſaid upon occaſion. And thus things have ſucceeded very well unto this very time. But from the middle of *October*, until this firſt of *February*, there having continued high South, and South-Weſt-Winds, with frequent and abundant Rains; it is no wonder that ſome innundation hath happened; but yet I will affirm, that greater miſchiefs would have followed, if the Mouth had been opened into *Serchio*. This which I have hitherto ſaid, is very clear and intelligible to all ſuch as have but competent inſight, and indifferent skill in theſe affairs. But that which I am now about to propoſe farther, will, I am very certain, be underſtood by your ſelf, but it will ſeem ſtrange and unlikely to many others. The point is, that I ſay, That by raiſing the level of *Fiume morto*, one half Brace, onely at its Mouth, (it will penipenitrate into *Serchio* farther than it would into the Sea) it ſhall cauſe the waters to riſe three, or perhaps more Braces upon the fields towards *Piſa*, and ſtill more by degrees as they ſhall recede farther from the Sea-ſide; and thus there will follow very great Innundations, and conſiderable miſchiefs. And to know that this is true, you are to take notice of an accident, which I give warning of in my diſcourſe of the Meaſure of Running Waters:

* *Lib.* 1.

where alſo I give the reaſon thereof, * *Coroll.* 14. The accident is this, That there coming a Land-Flood, for example, into *Arno*, which maketh it to riſe above its ordinary Mouth within *Piſa*, or a little above or below the City ſix or ſeven Braces; this ſame height becometh alwaies leſſer and leſſer, the more we approach towards the Sea-ſide; inſomuch, that near to the Sea the ſaid River ſhall be raiſed hardly half a Brace: Whence it followeth of neceſſary conſequence, that ſhould I again be at the Sea-ſide, and knowing nothing of what hapneth, ſhould ſee the River *Arno* raiſed by the acceſſion of a Land-flood, one third of a Brace; I could certainly infer, that the ſame River was raiſed in *Piſa* thoſe ſame ſix or ſeven Braces. And that which I ſay of *Arno*, is true of all Rivers that fall into the Sea. Which thing being true, it is neceſſary to make great account of every ſmall riſing, that F*iume morto* maketh towards the Sea-ſide by falling into *Serchio*. For although the riſing of F*iume morto*, by being to diſgorge its Waters into *Serchio*, towards the Sea, were onely a quarter of a Brace; we might very well be ſure, that farr from the Sea, about *Piſa*, and upon thoſe fields the riſe ſhall be much greater, and ſhall become two or three Braces: And becauſe the Countrey lyeth low, that ſame riſe will cauſe a continual Innundation, of the Plains, like as it did before; I cauſed the Mouth to be opened into the Sea. And therefore I conclude that the Mouth of F*iume morto*, ought by no means to be opened into *Serchio*, but ought to be continued into the Sea, uſing all diligence to keep it open after the manner aforeſaid, ſo ſoon as ever the Wind ſhall be laid. And if they ſhall do otherwiſe, I confidently affirm, that there will daily follow greater damages; not onely in the Plains, but alſo in the wholeſomneſs of the Air; as hath been ſeen in times paſt. And again, It ought with all care to be procured, that no waters do by any means run or fall from the Trench of *Libra*, into the Plain of *Piſa*, for theſe Waters being to diſcharge into F*iume morto*, they maintain it much higher than is imagined, according to that which I have demonſtrated in my conſideration upon the ſtate of the Lake of *Venice*. I have ſaid but little, but I ſpeak to you, who underſtandeth much, and I ſubmit all to the moſt refined judgment of our moſt Serene Prince *Leopold*, whoſe hands I beſeech you in all humility to kiſs in my name, and implore the continuance of his Princely favour to me; and ſo deſiring your prayers to God for me, I take my leave.

Your moſt affectionate Servant,

Rome 1. Feb. 1642.

D. BENEDETTO CASTELLI.

The

The anſwer to a Letter written by BARTOLOTTI, touching the difficultyes obſerved.

The former part of the Letter is omitted, and the diſcourſe beginneth at the firſt Head.

AND firſt I ſay, Whereas I ſuppoſe that the level of the *Serchio* is higher than that of *Fiume morto*; this is moſt true, at ſuch time as the waters of *Fiume morto* are diſcharged into the Sea; but I did never ſay that things could never be brought to that paſs, as that the level of *Fiume morto* ſhould be higher than *Serchio*: and ſo I grant that it will follow, that the waters of *Fiume morto* ſhall go into *Serchio*, and its very poſſible, that the Drain of *Fiume morto* into *Serchio* may be continuate; and I farther grant, that its poſſible, that the *Serchio* doth never diſgorge thorow *Fiume morto* towards *Piſa*; Nay, I will yet farther grant that it might have happened, that *Fiume morto* might have had ſuch a fall into *Serchio*, as would have ſufficed to have turned Mills: But then I add withall, that the Plains of *Piſa*, and the City it ſelf muſt be a meer Lake.

2. *Signore Bartolotti* ſaith confidently, that when the Sea ſwelleth by the South-Weſt, or other Winds, the level of *Serchio* in the place marked A in the Platt, diſtant about 200. Braces, riſeth very little: But that *Fiume morto* in D, and in E, many miles more up into Land riſeth very much, and that certain Fiſhermen confirm this, and ſhew him the ſignes of the riſing of the Water. I grant it to be very true, and I have ſeen it with my own eyes: But this cometh to paſs, when the Mouth of *Fiume morto* is ſtopt up by the Sea; as I ſhall ſhew by and by. And this riſing near the Sea-ſide, is of no conſiderable prejudice to the fields. And this is as much as I find to be true in the aſſertion of *Signore Bartolotti*, (without his confirming it by any other proof; as indeed it needs none) That the level of *Fiume morto* riſeth in E, and many miles farther upwards it riſeth much; nor did I ever affirm the contrary.

3. Concerning the difficulty of opening the Mouth of *Fiume morto* into the Sea, that which *Il Caſtellano* ſaith is moſt certain; namely, That at the entrance upon the opening of the Mouth, it is neceſſary to make a deep Trench: But I ſay, that at that time it is difficult to open it, unleſs upon great occaſions; for that the

difficulty proceedeth from the waters of *Fiume morto* being low, and the fields drained.

4. As to the particular of the Cauſes that you tell me men preſs ſo much unto the moſt *Serene Grand Duke*, and to the Prince, I have not much to ſay, becauſe it is not my profeſſion; nor have I conſidered of the ſame: Yet I believe, that when the Prince and his Highneſſe ſee the benefit of his People and Subjects in one ſcale of the Ballance, and the accomodation of Huntſmen in the other, his Highneſſe will incline to the profit of his ſubjects; ſuch have I alwayes found his Clemency and Nobleneſſe of minde. But if I were to put in my vote upon this buſineſſe, I would ſay, that the points of Spears, and the mouths of Guns, the yelping of Dogs, the wilyneſſe of Huntſmen, who run thorow and narrowly ſearch all thoſe Woods, Thickets and Heathes, are the true deſtroyers of Bucks and Boares, and not a little Salt-water, which ſetleth at laſt in ſome low places, and ſpreadeth not very far. Yet nevertheleſſe, I will not enter upon any ſuch point, but confine my ſelf ſolely to the buſineſſe before me.

5. That Experiment of joyning together the water of *Fiume morto*, and that of *Serchio* by a little trench to ſee what advantage the Level E hath upon the Level I, doth not give me full ſatisfaction, taken ſo particularly, for it may come to paſſe, that ſometimes E may be higher, and ſometimes A lower, and I do not queſtion but that when *Serchio* is low, and *Fiume morto* full of Water, the level of *Fiume morto* will be higher than that of *Serchio*. But *Serchio* being full, and *Fiume morto* ſcant of Water, the contrary will follow, if the Mouth ſhall be opened to the Sea. And here it ſhould ſeem to me, that it ought to be conſidered, that there is as much advantage from E to the Sea through the little Trench opened anew into *Serchio*, as from E to the Sea by the Mouth of *Fiume morto*. But the difficulty (which is that we are to regard in our caſe) is, that the courſe of the Waters thorow the Trench is three times longer than the courſe of the Mouth of *Fiume morto*, as appeareth by the Draught or Plat which you ſent me, which I know to be very exactly drawn, for that the ſituation of thoſe places are freſh in my memory. Here I muſt give notice, that the waters of *Fiume morto* determining thorow the Trench in *Serchio* (the waters of which *Fiume morto* are, for certain, never ſo low as the Sea) their pendency or declivity ſhall, for two cauſes, be leſſe than the pendency of thoſe waters through the Mouth towards the Sea, that is, becauſe of the length of the line through the Trench, and becauſe of the height of their entrance into *Serchio*, a thing which is of very great import in diſcharging the waters which come ſuddenly, as

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he ſhall plainly ſee, who ſhall have underſtood my Book of the Meaſure of Running Waters. And this was the Reaſon why all the Countrey did grow dry upon the opening of the Mouth into the Sea. And here I propoſe to conſideration that which the Peaſants about *Piſa* relate, namely, That the Water in the Fields doth no conſiderable harm by continuing there five or ſix, yea, or eight dayes. And thetefore the work of the Countrey is to open the Mouth of *Fiume morto*, in ſuch manner, that the Water being come, they may have the Trench free and ready, when that the Water cometh it may have a free drain, and may not ſtay there above eight or nine dayes, for then the overflowings become hurtful. It is to be deſired alſo, that if any Propoſition is produced touching theſe affairs, it might be propounded the moſt diſtinctly that may be poſſible, and not conſiſt in generals, eſpecially when the Diſpute is of the riſings, of velocity, of tardity, of much and little water; things that are all to be ſpecified by meaſures.

6. Your Letter ſaith, in the next place, that *Signore Bartolotti* confeſſeth, that if the Mouth of the *Fiume morto* might alwayes be kept open, it would be better to let it continue as it is: the which, that I may not yield to him in courteſie, I confeſſe, for the keeping it ſtopt on all ſides would be a thing moſt pernicious. But admitting of his confeſſion I again reply, that *Fiume morto* ought not to be let into *Serchio*, but immediately into the Sea; becauſe although ſometimes the Mouth to Seawards be ſtopt up, yet for all that, the raiſing of the Bank above the Plains (which is all the buſineſſe of importance) ſhall be ever leſſer, if we make uſe of the Mouth leading to the Sea, than uſing that of *Serchio*.

7. I will not omit to mention a kinde of ſcruple that I have concerning the poſition of *Sign. Bartolotti*, that is, where he ſaith that the two Mouths A and D are equal to the like Mouths into the Sea; Now it ſeems to me, that the Mouth A of *Fiume morto* into *Serchio* is abſolutely within *Serchio*, nor can it be made lower, and is regulated by the height of *Serchio*: But the Mouth of *Fiume morto* terminates, and ought to be underſtood to terminate in the Sea it ſelf, the loweſt place. And this I believe was very well perceived by *Sig. Bartolotti*, but I cannot tell why he paſt it over without declaring it: and we ſee not that the Mouth D falleth far from the Sea, which Mouth ought to be let into the Sea it ſelf, and ſo the advantage of the Mouth into the Sea more clearly appeareth.

8. That which *Sig. Bartolotti* addeth, that when it is high Waters, at ſuch time as the Waters are out, and when Winds choak up *Fiume morto*, they not only retard it, but return the courſe

courſe of the Waters upwards very leaſurely, perſwadeth me more readily to believe that *Sig. Bartolotti* knoweth very well, that the Mouth of *Fiume morto* let into *Serchio* is hurtful: for by this he acknowledgeth that the Mouth towards the Sea doth in ſuch ſort drain the Countrey of the Waters, as that they become very low; and therefore upon every little *impetus* the waters turn their courſe: And from the motions, being exceeding ſlow, is inferred, that the abundance of Sea-water that cometh into *Fiume morto*, is ſo much as is believed, and as *Sig. Bartolotti* affirmeth.

9. After that *Sig. Bartolotti* hath ſaid what he promiſeth above, namely, that when the Windes blowing ſtrongly do ſtop up *Fiume morto*, and not onely retard but turn the courſe upwards, the time being Rainy, and the Mouth of *Fiume morto* ſhut up, the Waves of the Sea paſſe over the Bank of *Fiume morto*; at that time, ſaith *Signore Bartolotti*, the Champain ſhall know the benefit of *Fiume morto* diſcharged into *Serchio*, and the mouth A ſhall ſtand alwayes open; and *Fiume morto* may alwayes conſtantly run out, as alſo the Rains and Rain-waters, although the hurtful Tempeſt ſhould laſt many dayes, &c. And I reply, that all the Art conſiſts in this; for the benefit of thoſe Fields doth not depend on, or conſiſt in ſaying, that *Fiume morto* is alwayes open, and *Fiume morto* draineth continually; But all the buſineſſe of profit lyeth and conſiſteth in maintaining the Waters low in thoſe Plaines, and thoſe Ditches, which ſhall never be effected whilſt the World ſtands, if you let *Fiume morto* into *Serchio*; but yet it may, by opening the mouth into the Sea: and ſo much reaſon and nature proveth, and (which importeth) Experience confirmeth.

10. In the tenth place I come to conſider the anſwer that was made to another Propoſition in the Letter which I writ to Father *Franceſco*, which prudently of it ſelf alone might ſerve to clear this whole buſineſſe. I ſaid in my Letter, That great account is to be made of every ſmall riſing and ebbing of the Waters neer to the Sea in *Fiume morto*, for that theſe riſings and fallings, although that they be ſmall neer to the Sea-ſide, yet nevertheleſſe, they operate and are accompanied by notable riſings and fallings within Land, and far from the Sea-ſide, and I have declared by an example of *Arno*, in which a Land-flood falling, that made it increaſe above its ordinary height within *Piſa* ſix or ſeven Braces, that this height of the ſame Flood becometh ſtill leſſer, the neerer we approach to the Sea-coaſts. Nor ſhall the ſaid River be raiſed hardly half a Brace; whereupon it neceſſarily followeth, that if I ſhould return to the Sea-ſide, and not knowing any think of that which happeneth at *Piſa*, and ſeeing the

the River *Arno* raised by a Land-flood half a Brace, I might confidently affirm the said River to be raised in *Pisa* those six or seven Braces, &c. From such like accidents I conclude in the same Letter, that it is necessary to make great account of every little rise that *Fiume morto* shall make towards the Sea. Now cometh *Bartolotti* (and perhaps because I knew not how to express my self better, understandeth not my Proposition) and speaketh that which indeed is true, but yet besides our case: Nor have I ever said the contrary; and withall doth not apply it to his purpose. Nay I say, that if he had well applyed it, this alone had been able to have made him change his opinion. And because he saith, that I said, that it is true, when the abatement proceedeth from some cause above, as namely by Rain, or opening of Lakes; But when the cause is from below, that is, by some stop, as for instance some Fishers Wears or Locks, or some impediment remote from the Sea, although at the Level it shall rise some Braces where the impediment is, yet that rising shall go upwards; and here he finisheth his Discourse, and concludeth not any thing more. To which I say first, that I have also said the same in the Proposition, namely, that a Flood coming (which maketh *Arno* to rise in *Pisa* six or seven Braces (which I take to be a superiour cause whether it be Rain or the opening of Lakes, as best pleaseth *Bartolotti*) in such a case I say, and in no other (for towards the Sea-coasts it shall not cause a rising of full half a Brace; and therefore seeing *Arno* at the Sea-side to be raised by a Flood, whether of Rain, or of opening of Lakes half a Brace) it may be inferred, that at *Pisa* it shall be raised those six or seven Braces; which variety, well considered, explaineth all this affair in favour of my opinion: For the rising that is made by the impediment placed below, of Fishing Weares and Locks, operateth at the beginning, raising the Waters that are neer to the impediment; and afterwards less and less, as we retire upwards from the impediment: provided yet that we speak not of a Flood that cometh by accession, but onely of the ordinary Water impeded. But there being a new accession, as in our case, then the Water of the Flood, I say, shall make a greater rising in the parts superiour, far from the impediment; and these impediments shall come to be those that shall overflow the Plains, as happened eighteen or nineteen years ago, before the opening of *Fiume morto* into the Sea; The same will certainly follow, if *Fiume morto* be let into *Serchio*. Here I could alledge a very pretty case that befell me in *la* * *Campagna di Roma*, neer to the Sea-side, where I drained a Bog or Fen, of the nature of the Waters of *Pisa*, and I succeeded in the enterprize, the Waters in their site towards the Sea abating only three Palmes, and yet in the Fen

* The Countrey or Province lying round the City heretofore called *Latium*

Fen they fell more than fifteen Palmes. But the buſineſſe would be long, and not ſo eaſily to be declared, and I am certain that *Sig. Bartolotti* having conſidered this, would alter his judgment, and withall would know that remitting that impediment anew, which I had left for leſſe than three Palmes towards the Sea, the Waters in the Fen would return with the firſt Floods and Raines to the ſame height as before, as likewiſe *Fiume morto* will do if it ſhall be let again into *Serchio*.

Here I intreat your Honour to do me the favour to importune *P. Franceſco* in my behalf, that he would be pleaſed to declare my meaning in the aforeſaid Letter to *Sig. Bartolotti*, for I hope that if he will underſtand this point, he will be no longer ſo tenacious in his opinion.

Next that theſe Lords in the Commiſſion of Sewers, with the Right Honourable the Marqueſſe of S. *Angelo*, and your Honour do approve of my judgment, doth very much rejoyce me; but becauſe that I know that they do it not in deſign to complement me, but onely to ſerve his Highneſs our Grand Duke, I freely profeſs that I will pretend no farther obligations from them therein, than I account my ſelf to owe to thoſe whoſe opinions are contrary to mine, for that I know that they have the ſame end. The definitive ſentence of this whole buſineſs is, that they give theſe Plains, theſe Draines, and theſe Waters farre fetcht appellations.

11. As to the quantity of the Water that *Fiume morto* diſchargeth into the Sea, there are very great diſputes about it, and I have been preſent at ſome of them. But let your Honour believe me, that as this is not continual, but only during a few dayes, ſo it will never be of any great prejudice to theſe Fields; and if your Lordſhip would be aſcertained thereof, you may pleaſe to go to *Fiume morto* at about a mile's diſtance from the Sea, in the time of theſe ſtrong Windes, and obſerve the current from thence upwards, for you ſhall finde it extream ſlow, and conſequently will know that the quantity of the Water that is repuls'd is very ſmall. And this ſeems to be contradicted by the rule of Riſings proceeding from cauſes below, which occaſion no conſiderable alteration far from the Sea.

I am neceſſitated to go to morrow out of *Rome* with his Eminence Cardinal *Gaetano* about certain affairs touching Waters, therefore I ſhall not farther inlarge, but for a cloſe to this tedious Diſcourſe, I conclude in few words, that *Fiume morto* is by no means to be let into *Serchio*, nor are there any means of mediate courſes to be taken, for they will alwayes be prejudicial; but *Fiume morto is* to be diſcharged immediately into the Sea. When it is ſtopt up by the ſurly of the Sea-waves, I affirm that it is a

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ſign that there is no need of opening it; and if there be any occaſion to open it, it is eaſily done. As for the reſt your Lordſhip may pleaſe to keep account of all the particulars that occur, for the memory of things paſt is our Tutreſſe in thoſe that are to come. If occaſion ſhall offer, I intreat you to bow humbly in my name to His Highneſs the Grand Duke, and the moſt Serene Prince *Leopold*; and to attend the ſervice of Their Highneſſes, for you ſerve Princes of extraordinary merit; And to whom I my ſelf am alſo exceedingly obliged. In the controverſies that ariſe reſpect the pious end of ſpeaking the Truth, for then every thing will ſucceed happily. I kiſs the hands of *Padre Franceſco*, of *Sig. Bartolotti*, and of your Lordſhip.

Your Honours

Rome, 14. *March* 1642.

moſt Obliged Servant

D. *BENEDETTO CASTELLI.*

Upon this occaſion I will here inſert a Diſcourſe that I made upon the Draining and improvement of the *Pontine Fens*, for that I think that whatſoever may be done well and to purpoſe in this matter hath abſolute dependance on the perfect knowledge of that ſo important Propoſition, by me demonſtrated and explained in my Treatiſe of the *Menſuration* of *Running Waters*, namely, That the ſame water of a River doth continually change Meaſures, according as it altereth and changeth the velocity of its courſe; ſo that the meaſure of the thickneſſe of a River in one Site, to the meaſure of the ſame River in another Site, hath the ſame proportion reciprocally that the velocity in this ſite hath to the velocity in the firſt ſite. And this is a Truth ſo conſtant and unchangeable, that it altereth not in the leaſt point on any occurrences of the Waters that change: and being well underſtood, it openeth the way to the knowledge of ſundry advertiſements in theſe matters, which are all reſolved by this ſole Principle; and from it are derived very conſiderable benefits; and without theſe it is impoſſible to do any thing with abſolute perfection.

A

CONSIDERATION

Upon the

DRAINING

OF THE

Pontine Fenns.

BY

D. BENEDETTO CASTELLI, Abbot of S. BENEDETTO AL OISIO, and Professor of the *Methematicks* to P. *Urban* VIII. in the University of *ROME*.

CONSIDERATION III.

AMongst the enterprizes by me esteemed, if not absolutely impossible, , at least exceeding difficult, one was that famous one of Draining the *Pontine Fenns*; and therefore I was thorowly resolved never to apply my minde thereunto, although by my Patrons I should be commanded to the same: accounting that it was an occasion rather of losing reputation by the miscarriage of the attempt, than of gaining fame by reducing things to a better pass then they now are at. Yet nevertheless, having of late years observed the place, and sailed through those Chanels, and those Waters; after I had made some reflection thereupon, I thought that the enterprize was not so difficult as I had at first conceited it to be; and I am the more confirmed in this opinion, upon the inducement of that which I have written

Geometrically in my Treatiſe of the Menſuration of Running Waters; ſo that talking with ſeveral perſons, I adventured to affirm, in diſcoures, that this improvement might poſſibly be brought into a good eſtate.

Now I have reſolved to ſet down my thoughts in writing, and to honour this my Paper with the Noble Name of your Lordſhip, to render it the more credible and conſpicuous at the firſt view, if it ſhould chance that the Subject I treat of, were not of ſuch moment, as that it did deſerve to be valued for any other reaſon. Pardon me, Sir, if I have been too bold, and continue me in the number of your Servants.

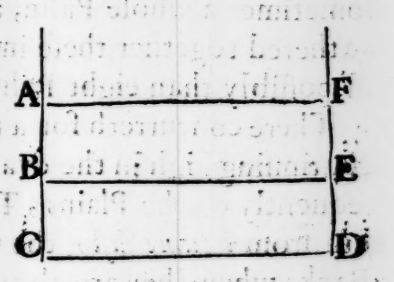
The enterprize of Draining a great part of the Territories of the *Pontine Fenns*, hath been undertaken both in the time of the antient *Romans*, and laſt of all, in our days; yea in the late times by *Sixtus* V. I do not doubt in the leaſt, but that it will be poſſible yet to reduce things to a very good paſs; and if I be not miſtaken, with a very ſmall charge in compariſon of the profit that would be received from thoſe rich Grounds. This improvement was of great expence in the time of *Sixtus Quintus*, but by reaſon the thing was not rightly underſtood, there were made many Drains; a great part of which were unprofitable and vain: and amongſt ſo many operations, there hapned ſome to be made that ſucceeded, as was deſired; but not being underſtood, they were held in no account; and thus the buſineſs being neglected, the waters are returned into the ſame ſtate as they were at firſt, before the improvement. Here I have by familiar diſcourſes with my friends, explained this enterprize undertaken by *Sixtus* V. and haply alſo by ſome more antient, with the example of the Fable of *Orilo*, in *Arioſto*. This Monſter was made up with ſuch enchantment, that men fought with him alwayes in vain; for though in the Combate he were cut in pieces, thoſe divided Members preſently re-united, and returned to the fight more fierce then ever. But the *Paladine Aſtolfo* coming to undertake him, after a long diſpute, at the end he cut his head ſheer off from the ſhoulders at one blow; and nimbly alighting from his Horſe, took the Monſtrous head, and mounting again, as he rid away he fell to ſhave the Pole of that Monſter, and ſo he loſt the Lock of Hair, in which alone the enchantment lay; and then the horrible Head in an inſtant manifeſted ſigns of death, and the trunk which ran, ſeeking to reunite to it anew, gave the laſt gaſp, and in this manner the enchantment ended. The Book of Fate ſerved admirably to the *Paladine*, whereby he came to underſtand that Charm; for by ſhaving his whole head, the enchanted hairs came to be cut off amongſt the reſt: In the ſame manner, I ſay, that it hath ſometimes happened in Draining thoſe Fields;

for

for that amongſt ſo many tryals as have been made, that alſo was light upon, on which the improvement and remedy to the diſorder did depend. And to us my fore-named Treatiſe ſhall ſerve for a Rule, which being well underſtood, ſhall make us to know wherein conſiſteth, and whereon dependeth this miſcarriage, and conſequently it will be eaſie to apply thereunto a ſeaſonable remedy.

And firſt I ſay, That there is no doubt but that the waters continue ſo high on thoſe Plains becauſe they are ſo high in the principal River, which ought to receive them, and carry them into the Sea. Now the Cauſes of the height of the River, may in my judgement be reduced to one alone; which is that by me ſo often mentioned for the moſt Potent one, and declared in my afore-named Tractate; to wit, The tardity of the motion of the waters, which doth alwayes infallibly, and preciſely cauſe the ſelf ſame Running Water to change the meaſure of its thickneſs at ſuch a rate, that the more it encreaſeth in velocity, the more it decreaſeth in meaſure; and the more it decreaſeth in velocity, the more it encreaſeth in meaſure: As for example; If a River run in ſuch a place with the velocity of moving a mile in the ſpace of an hour, and afterwards the ſame River in another place doth encreaſe in velocity, ſo as to make three miles an hour; that ſame River ſhall diminiſh in thickneſs two thirds: And on the contrary, If it ſhall diminiſh in velocity ſo, as that it runneth but half a mile in the ſame time, it ſhall encreaſe the double in thickneſs and meaſure. And in a word, look what proportion the velocity in the firſt place, hath to the velocity in the ſecond, and ſuch hath reciprocally the meaſure of the thickneſs in the ſecond place, to the meaſure in the firſt; as I have clearly demonſtrated in my Treatiſe: Which I repeat ſo frequently, that I fear the Profeſſors of Polite Learning will charge me with Tuatologie, and vain Repetition. But I am ſo deſirous in this moſt important point to be well underſtood, becauſe it will then be eaſie to comprehend all the reſt; and without this it is impoſſible (I will not ſay difficult, but abſolutely impoſſible) to underſtand, or ever to effect any thing to purpoſe. And the better to explain the example, let it be ſuppoſed,

That the water of a River A D, runneth high at the level of A F, with ſuch a certain velocity; and let it, by the ſame water, be velocitated three times more; I ſay, that it will abate ⅓, and ſhall ſtand at the level in B E; and if it ſhall more velocitate, it will abate the more at the Sea; But if it ſhould retard



more

more than it did at the level A F, it would riſe yet more above the ſaid level A F; although that the ſelf ſame quantity of water runneth all the while. By the above-named ſolid Principle I reſolve extravagant Problems in my Treatiſe, and aſſign the Reaſons of admirable effects of Running Waters: But as for what concerneth our purpoſe of the *Pontine Fenns*, we have the Cauſes very plain and clear; for which, by the trampling of Cattle which paſs thorow the *Draining River*, the waters abate ſo notably, that it is as it were a miracle for thoſe Reeds, Flags, and Weeds that ſpring up, encreaſe, and ſpread all over the River, ſtop and impede that velocity of the waters which they would have by means of their declivity. But that paſſage of thoſe Beaſts, treading down thoſe Weeds unto the bottom of the River, in ſuch ſort, as that they no longer hinder the Current of the Water; and the ſame Waters increaſing in their courſe, they do diminiſh in meaſure and height; and by this meanes the Ditches of the Plains empty into the ſame ſucceſsfully, and leave them free from Waters, and Drained. But theſe Weeds in a ſhort time ſprouting up anew, and raiſing their ſtalkes thorow the body of the Waters, they reduce things to the ſame evil ſtate, as before, retarding the velocity of the Water, making it to increaſe in height, and perhaps do occaſion greater miſchiefs; ſeeing that thoſe many knots which each plant ſhoots forth, begets a greater multitude of Stalks; which much more incumbering the Water of the River, are a greater impediment unto its velocity, and conſequently make the height of the waters to encreaſe ſo much the more, and do more miſchief than before.

Another head to which theſe harms may be reduced, but proceeding from the ſame Root, which hath a great part in this diſorder, is the impediment of thoſe Wears in the River which are made by heightning the bed of the ſame, for placing of fiſhing-nets; of which *Piſcaries* I reckoned above ten, when I made a voyage thorow thoſe waters to *Sandolo*. And theſe Fiſhing-Wears are ſuch impediments, that ſome one of them makes the water of the River in the upper part to riſe half a Palm, and ſometimes a whole Palm, and more; ſo that when they are all gathered together, theſe impediments amount to more than ſeven, or poſſibly than eight Palms.

There concurreth for a third moſt Potent Cauſe of the waters continuing high in the evacuating, or Draining Chanel, and conſequently on the Plains; The great abundance of water that iſſueth from *Fiume Siſto*, the waters of which do not keep within its Banks when they are abundant; but encreaſing above its Chanel, they unite with thoſe of the Evacuator, and diſperſing thorow

the

the Fens are raiſed with great prejudice, and much greater than is conceived, according to what hath been demonſtrated in the Second Conſideration upon the *Lake of Venice*. Nor is it to any purpoſe to ſay, that if we ſhould meaſure all the Waters that disimbogue from *Fiume Siſto*, and gather them into one ſumme, we ſhould not finde them to be ſuch, as that they ſhall be able to make the Waters of the Fens to increaſe, by reaſon of the great expanſion of them, over which that body of water is to diſtend: for to this inſtance we anſwer with that which we have given notice of in the Firſt Conſideration touching the *Lake of Venice*, treating of the abatement that is cauſed by the *Brent* let into the Lake. And moreover, if I ſhall adde thereto that which I write in the Second Conſideration, it will be very apparent how greatly harmfull and prejudicial theſe excurſions of Waters from *Fiume Siſto* may be, which are not kept under, and confined within the River: Therefore, proceeding to the proviſions, and operations that are to be accounted Principall, I reduce them to three Heads.

In the firſt place it is neceſſary to throw down thoſe Weares, and to take the Piſciaries quite away, obſerving a Maxime, in my judgment, infallible, that Fiſhing and Sowing are two things that can never conſiſt together; Fiſhing being on the Water, and Sowing on land.

Secondly, it will be neceſſary to cut under Water in the bottome of the River thoſe Weeds and Plants that grow and increaſe in the River, and leave them to be carried into the Sea by the Stream; for by this means theſe Reeds ſhall not ſpring up and diſtend along the bottome of the River, by means of the Beaſts treading upon them; And the ſame ought to be done often, and with care, and muſt not be delaied till the miſchief increaſe, and the Champain Grounds be drowned, but one ought to order matters ſo, as that they may not drown. And I will affirm, that otherwiſe this principal point would become a moſt conſiderable inconvenience.

Thirdly, it is neceſſary to make good the Banks of *Fiume Siſto*, on the left hand, and to procure that thoſe Waters may run in the Chanel, and not break forth. And it is to be noted, that it is not enough to do one or two of thoſe things, but we are to put them all in execution; for omitting any thing, the whole machine will be out of tune, and ſpoiled. But proceeding with due care, you ſhall not only Drain the *Pontine Fens*, but by means of this laſt particular the Current of *Fiume Siſto* ſhall ſcowr its own Chanel of its ſelf, even to the carrying part of it away: and haply with this abundance of water that it ſhall bear

bear, the Mouth *della Torre* may be opened, and kept open into the Sea. And it would, laſt of all, be of admirable benefit to cleanſe *Fiume Sisto* from many Trees and Buſhes wherewith it is overgrown.

And with this I conclude, that the Improvement or Drain poſſible to be made conſiſteth in theſe three particulars. Firſt, in taking away the Fiſhing Weares, leaving the Courſe of the Waters free. Secondly, in keeping the Prineipal Rivers clear from Weeds and Plants. Thirdly, in keeping the water of *Fiume Sisto* in its own Chanel. All which are things that may be done with very little charge, and to the manifeſt benefit of the whole Country, and to the rendering the Air wholſomer in all thoſe Places adjoyning to the *Pontine Fens.*

A

CONSIDERATION

Upon the

DRAINING

Of the Territories of

Bologna, Ferrara,

AND

Romagna.

BY

D. BENEDETTO CASTELLI, Abbot of S. BENEDETTO ALOISIO, *Mathematician* to P. *Urban* VIII. and Profeſſor in the Univerſity of *ROME*.

THe weghty buſineſſe of the Draining of the Territories of *Bologna*, *Ferrara*, and *Romagna* having been punctually handled and declared in writing from the excellent memory of the Right Honourable and Noble *Monſignore Corſini*, who was heretofore Deputed Commiſſary General, and Viſitor of thoſe Waters; I am not able to make ſuch another Diſcourſe upon the ſame Subject, but will only ſay ſomewhat for farther confirmation of that which I have ſaid in this Book upon the *Lake of Venice*, upon the *Pontine Fens*, and upon the Draining of thoſe Plains of *Piſa*, lying between the Rivers *Arno* and *Serchio*; whereby it is manifeſt, that in all the

aforementioned Caſes, and in the preſent one that we are in hand with, there have, in times paſt, very groſſe Errours been committed, through the not having ever well underſtood the true meaſure of Running waters; and here it is to be noted, that the buſineſſe is, that in *Venice*, the diverſion of the waters of the Lake, by diverting the *Brent* was debated, and in part executed, without conſideration had how great abatement of water might follow in the Lake, if the *Brent* were diverted, as I have ſhewn in the firſt Conſideration upon this particular, from which act there hath inſued very bad conſequences, not only the difficulty of Navigation, but it hath infected the wholſomneſſe of the Air, and cauſed the ſtoppage of the Ports of *Venice*. And on the contrary, the ſame inadvertency of not conſidering what riſing of the Water the *Reno*, and other Rivers being opened into the Valleys of *Bologna* and *Ferrara*, might cauſe in the ſaid Valleys, is the certain cauſe that ſo many rich and fertile Fields are drowned under water, converting the happy habitations and dwellings of men into miſerable receptacles for Fiſhes: Things which doubtleſſe would never have happened, if thoſe Rivers had been kept at their height, and *Reno* had been turn'd into *Main-Po*, and the other Rivers into that of *Argenta*, and of *Volano*. Now there having ſufficient been ſpoken by the above-named *Monſig. Corſini* in his Relation, I will only adde one conceit of my own, which after the Rivers ſhould be regulated, as hath been ſaid, I verily believe would be of extraordinary profit, I much doubt indeed that I ſhall finde it a hard matter to perſwade men to be of my mind, but yet nevertheleſs I will not queſtion, but that thoſe, at leaſt, who ſhall have underſtood what I have ſaid and demonſtrated concerning the manners and proportions, according to which the abatements and riſings of Running waters proceed, that are made by the Diverſions and Introductions of VVaters, will apprehend that my conjecture is grounded upon Reaſon. And although I deſcend not to the exactneſſe of particulars, I will open the way to others, who having obſerved the requiſite Rules of conſidering the quantity of the waters that are introduced, or that happen to be diverted, ſhall be able with punctuality to examine the whole buſineſſe, and then reſolve on that which ſhall be expedient to be done.

Reflecting therefore upon the firſt Propoſition, that the Riſings of a Running Water made by the acceſſion of new water into the River, are to one another, as the Square-Roots of the quantity of the water that runneth; and conſequently, that the ſame cometh to paſs in the Diverſions: Inſomuch, that a River running in height one ſuch a certain meaſure, to make it encreaſe double in height, the water is to be encreaſed to three times as much

much as it ran before; ſo that when the water ſhall be quadruple, the height ſhall be double; and if the water were centuple, the height would be decuple onely, and ſo from one quantity to another: And on the contrary, in the Diverſions; If of the 100. parts of water that run thorow a River, there ſhall be diverted $\frac{10}{100}$, the height of the River diminiſheth onely $\frac{1}{10}$, and continuing to divert $\frac{17}{100}$, the height of the River abateth likewiſe $\frac{1}{10}$, and ſo proceeding to divert $\frac{15}{100}$ and then $\frac{13}{100}$, and then $\frac{11}{100}$, and then $\frac{9}{100}$, and then $\frac{7}{100}$, and then $\frac{5}{100}$, and then $\frac{3}{100}$, alwaies by each of theſe diverſions, the height of the Running Water diminiſheth the tenth part: although that the diverſions be ſo unequal. Reflecting I ſay upon this infallible Truth, I have had a conceit, that though the *Reno* and other Rivers were diverted from the Valleyes, and there was onely left the *Chanel of Navigation*, which was onely the $\frac{1}{10}$ part of the whole water that falleth into the Valleys; yet nevertheleſs, the water in thoſe ſame Valleyes would retain a tenth part of that height that became conjoyned by the concourſe of all the Rivers: And therefore I ſhould think that it were the beſt reſolution to maintain the *Chanel of Navigation* (if it were poſſible) continuate unto the *Po* of *Ferrara*, and from thence to carry it into the *Po* of *Volano*, for beſides that it would be of very great eaſe in the Navigation of *Bologna*, and *Ferrara*, the ſaid water would render the *Po* of *Volano* navigable as far as to the very Walls of *Ferrara*, and conſequently the Navigation would be continuate from *Bologna* to the Sea-ſide.

But to manage this enterprize well, it is neceſſary to meaſure the quantity of the Water that the Rivers diſcharge into the Valleys, and that which the *Chanel of Navigation* carryeth, in manner as I have demonſtrated at the beginning of this Book; for this once known, we ſhall alſo come to know, how profitable this diverſion of the *Chanel of Navigation* from the Valleys is like to prove; which yet would ſtill be unprofitable, if ſo be that all the Rivers that diſcharge their waters into the Valleys, ſhould not firſt be Drained, according to what hath been above advertiſed.

Abbot CASTELLI, *in the preſent conſideration referring himſelf to the Relation of* Monſig. Corſini, *grounded upon the Obſervations and Precepts of the ſaid Abbot; as is ſeen in the preſent Diſcourſe. I thought it convenient for the compleating of the Work of our Authour, upon theſe ſubjects, to inſert it in this place.*

A Relation of the Waters in the Territories of *Bologna* and *Ferrara*.

BY

The Right Honourable and Illuſtrious, *Monſignore* CORSINI, a Native of *Tuſcany*, Superintendent of the general DRAINS, and Preſident of *Romagna*.

THE *Rheno*, and other Brooks of *Romagna*, were by the advice of *P. Agoſtino Spernazzati* the Jeſuite, towards the latter end of the time of *Pope Clement* VIII. notwithſtanding the oppoſition of the *Bologneſi*, and others concerned therein, diverted from their Chanels, for the more commodious cleanſing of the *Po* of *Ferrara*, and of its two Branches of *Primaro*, and *Volano*; in order to the introducing the water of the *Main*-*Po* into them, to the end that their wonted Torrents being reſtored, they might carry the Muddy-water thence into the Sea, and reſtore to the City the Navigation which was laſt, as is manifeſt by the Brief of the ſaid *Pope Clement*, directed to the *Cardinal San Clemence*, bearing date the 22. of *Auguſt*, 1604.

The work of the ſaid cleanſing, and introducing of the ſaid *Po*, either as being ſuch in it ſelf, or by the contention of the *Cardinal Legates* then in theſe parts; and the jarrings that happened betwixt them, proved ſo difficult, that after the expence of vaſt ſumms in the ſpace of 21. years, there hath been nothing done, ſave the rendring of it the more difficult to be effected.

Interim, the Torrents with their waters, both muddy and clear, have damaged the Grounds lying on the right hand of the *Po* of *Argenta*, and the *Rheno* thoſe on its Banks; of which I will ſpeak in the firſt place, as of that which is of greater importance, and from which the principal cauſe of the miſchiefs that reſult from the reſt doth proceed.

This *Rheno* having overflowed the * Tennency of *Sanmartina*, in circumference about fourteen miles given it before, and part of that of *Cominale* given it afterwards, as it were, for a receptacle; from whence, having depoſed the matter of its muddineſs, it iſſued clear by the Mouths of *Maſi*, and of *Lievaloro*, into the *Po* of *Primaro*, and of *Volano*; did break down the encompaſſing

* Or Lordſhip.

paſſing Bank or Dam towards S. *Martino*, and that of its new Chanel on the right hand neer to *Torre del Fondo*.

By the breaches on this ſide it ſtreamed out in great abundance from the upper part of *Cominale*, and in the parts about *Raveda*, *Pioggio*, *Caprara*, *Ghiare di Reno*, *Sant' Agoſtino*, *San Proſpero*, *San Vincenzo*, and others, and made them to become incultivable: it made alſo thoſe places above but little fruitful, by reaſon of the impediments that their Draines received, finding the Conveyances called *Riolo* and *Scorſuro*, not only filled by *la Motta* and *la Belletta*, but that they turned backwards of themſelves.

But by the Mouths in the incloſing Bank or Dam at *Borgo di S. Martino* iſſuing with violence, it firſt gave obſtruction to the ancient Navigation of *la Torre del la Foſſa*, and afterwards to the moderne of the mouth of *Maſi*, ſo that at preſent the Commerce between *Bologna* and *Ferrara* is loſt, nor can it ever be in any durable way renewed, whilſt that this exceeds its due bounds, and what ever moneys ſhall be imployed about the ſame ſhall be without any equivalent benefit, and to the manifeſt and notable prejudice of the * Apoſtolick Chamber.

* The Popes Exchequer.

Thence paſſing into the Valley of *Marzara*, it ſwelleth higher, not only by the riſing of the water, but by the raiſing of the bottome, by reaſon of the matter ſunk thither after Landfloods, and dilateth ſo, that it covereth all the Meadows thereabouts, nor doth it receive with the wonted facility the Drains of the upper Grounds, of which the next unto it lying under the waters that return upwards by the Conveyances, and the more remote, not finding a paſſage for Rain-waters that ſettle, become either altogether unprofitable or little better.

From this Valley, by the Trench or Ditch of *Marzara*, or of *la Duca* by *la Buova*, or mouth of *Caſtaldo de Roſſi*, and by the new paſſage it falleth into the *Po* of *Argenta*, which being to receive it clear, that ſo it may ſink farther therein, and receiving it muddy, becauſe it hath acquired a quicker courſe, there will ariſe a very contrary effect.

Here therefore the ſuperficies of the water keeping high, until it come to the Sea, hindereth the Valleys of *Ravenna*, where the River *Senio*, thoſe of *San Bernardino* where *Santerno* was turned, thoſe of *Buon' acquiſto*, and thoſe of *Marmorto*, where the *Idice*, *Quaderna*, *Sellero* fall in, from ſwallowing and taking in their Waters by their uſual In-lets, yet many times, as I my ſelf have ſeen in the *Viſitation*, they drink them up plentifully, whereupon, being conjoyned with the muddineſſe of thoſe Rivers that fall into the ſame, they ſwell, and dilate, and overflow ſome grounds, and deprive others of their Drains in like manner

as

as hath been ſaid of that of *Marrara*, inſomuch that from the Point of S. *Giorgio*, as far as S. *Alberto* all thoſe that are between the Valleys and *Po* are ſpoiled, of thoſe that are between Valley and Valley many are in a very bad condition, and thoſe that are ſome conſiderable ſpace above not a little damnified.

In fine, by raiſing the bottom or ſand of the Valleys, and the bed of *Reno*, and the too great repletion of the *Po* of *Primaro* with waters, the Valleys of *Comacchio* (on which ſide the Banks are very bad) and * *Poleſine di* S. *Giorgio* are threatned with a danger, that may in time, if it be not remedied, become irreparable, and at preſent feeleth the incommodity of the Waters, which penetrating thorow the pores of the Earth do ſpring up in the ſame, which they call *Purlings*, which is all likely to redound to the prejudice of *Ferrara*, ſo noble a City of *Italy*, and ſo important to the *Eccleſiaſtick State*.

† *Poleſine* is a plat of Ground almoſt ſurrounded with Bogs or waters, like an Iſland

Which particulars all appear to be atteſted under the hand of a Notary in the *Viſitation* which I made upon the command of His Holineſſe, and are withall known to be true by the **Ferrareſi* themſelves, of whom (beſides the requeſt of the *Bologneſi*) the greater part beg compaſſion with ſundry *Memorials*, and remedies, aſwell for the miſchiefs paſt, as alſo for thoſe in time to come, from which I hold it a duty of Conſcience, and of Charity to deliver them.

* People of *Ferrara*.

Pope *Clement* judged, that the ſufficient means to effect this was the ſaid Introduction of the *Main* *Po* into the Chanel of *Ferrara*; a reſolution truly Heroical, and of no leſſe beauty than benefit to that City, of which I ſpeak not at preſent, becauſe I think that there is need of a readier and more accomodate remedy.

So that I ſee not how any other thing can be ſo much conſiderable as the removal of *Reno*, omitting for this time to ſpeak of *incloſing it from Valley to Valley untill it come to the Sea, as the Dukes of *Ferrara* did deſign, foraſmuch as all thoſe *Ferrareſi* that have intereſt in the *Poleſine di* S. *Giorgio*, and on the right hand of the *Po* of *Argenta* do not deſire it, and do, but too openly, proteſt againſt it; and becauſe that before the Chanel were made as far as the Sea, many hundreds of years would be ſpent, and yet would not remedy the dammages of thoſe who now are agrieved, but would much increaſe them, in regard the Valleys would continue ſubmerged, the Drains ſtopped, and the other Brooks obſtructed, which would of neceſſity drown not a few Lands that lie between Valley and Valley; and in fine, in regard it hath not from *San Martina* to the Sea for a ſpace of fifty miles a greater fall then 19, 8, 6, feet, it would want that force which they themſelves who propound this project do require it to have

* In Chanels made by hand.

have, that ſo it may not depoſe the matter of the muddineſs when it is intended to be let into *Volana*.

So that making the Line of the bottome neer to *Vigarano*, it would riſe to thoſe prodigious termes that they do make bigger, and they may thence expect thoſe miſchiefs, for which they will not admit of introducing it into the ſaid *Po* of *Volana*.

Amongſt the wayes therefore that I have thought of for effecting that ſame remotion, and which I have cauſed to be viewed by skilful men that have taken a level thereof, (with the aſſiſtance of the venerable Father, *D. Benedetto Caſtelli* of *Caſina*, a man of much fidelity and honeſty, and no leſs expert in ſuch like affairs touching waters, than perfect in the *Mathematick* Diſciplines) two onely, the reſt being either too tedious, or too dangerous to the City, have ſeemed to me worthy, and one of them alſo more than the other, to offer to your Lordſhip.

The one is to remit it into the Chanel of *Volana*, thorow which it goeth of its own accord to the Sea.

The other is to turn it into *Main-Po* at *Stellata*, for, as at other times it hath done, it will carry it to the Sea happily.

As to what concerns the making choice of the firſt way, that which ſeemeth to perſwade us to it is, that we therein do nothing that is new, in that it is but reſtored to the place whence it was removed in the year 1522. in the time of Pope *Adrian*, by an agreement made in way of contract, between *Alfonſo*, Duke of *Ferrara*, and the *Bologneſi*; and that it was diverted for reaſons, that are either out of date, or elſe have been too long time deferred.

In like manner the facility wherewith it may be effected, letting it run into the divided *Po*, whereby it will be turned to *Ferrara*, or elſe carrying it by *Torre del Fondo*, to the mouth of *Maſi*, and from thence thorow the Trench made by the *Ferrareſi*, along by *Panaro*, where alſo finding an ample Bed, and high and thick Banks, that will ſerve at other times for it, and for the waters of *Po*, there may a great expence be ſpared.

That what ever its Fall be, it would maintain the ſame, not having other Rivers, which with their Floods can hinder it; and that running confined between good Banks, without doubt it would not leave *la Motto* by the way; but eſpecially, that it would be ſufficient if it came to *Codigoro*, where being aſſiſted by the Ebbing and Flowing of the Sea, it would run no hazard of having its Chanel filled up from thence downwards.

That there might thence many benefits be derived to the City, by means of the Running Waters, and alſo no mean Navigation might be expected.

On the contrary it is objected, That it is not convenient to think

think of returning this Torrent into the divided *Po*, by reaſon of the peril that would thence redound to this City.

And that going by *Torre del Fondo*, through *Sanmartina* to the Mouth *de Maſi* by the Chappel of *Vigarano* unto the Sea, it is by this way 70. miles; nor is the Fall greater than 26.5.6. Feet, ſo that it would come to fall but 4. inches & an half, or thereabouts in a mile; whereas the common opinion of the skilfull (to the end that the Torrents may not depoſe their ſand that they bring with them in Land-Floods) requireth the twenty fourth part of the hundredth part of their whole length, which in our caſe, accounting according to the meaſure of theſe places, is 16. inches a * mile; whereupon the ſinking of the Mud and Sand would moſt certainly follow, and ſo an immenſe heightning of the Line of the Bottom, and conſequently a neceſſity of raiſing the Banks, the impoſſibility of maintaining them, the danger of breaches and decayes, things very prejudicial to the *Iſlets* of this City, and of *San Giorgio*, the obſtruction of the Drains, which from the Tower of *Tienne* downwards, fall into the ſaid Chanel; to wit, thoſe of the Sluices of *Goro*, and the Drains, of the Meadows of *Ferrara*: And moreover, the damages that would ariſe unto the ſaid *Iſlet* of S. *Giorgio*, and the Valleys of *Comachio*, by the waters that ſhould enter into the *Goro* or Dam of the Mills of *Belriguardo*, thorow the Trenches of *Quadrea*, which cannot be ſtopt, becauſe they belong to the Duke of *Modena*, who hath right of diverting the waters of that place at his pleaſure to the work of turning Mills.

* The inch of theſe places is ſomewhat bigger than ours.

The greater part of which Objections, others pretend to prove frivolous, by ſaying, that its running there till at the laſt it was turned another way, is a ſign that it had made ſuch an elevation of the Line, of its Bed as it required; denying that it needeth ſo great a declivity as is mentioned above; and that for the future it would riſe no more.

That the ſaid Dra ns and Ditches did empty into the ſame, whilſt *Po* was there; ſo that they muſt needs be more able to do ſo when onely *Reno* runs that way.

That there would no Breaches follow, or if they did, they would be onely of the water of *Reno*, which in few hours might be taken away (in thoſe parts they call damming up of Breaches, and mending the Bank, *taking away the Breaches*) and its a queſtion whether they would procure more inconvenience than benefit, for that its Mud and Sand might in many places, by filling them up, occaſion a ſeaſonable improvement.

Now omitting to diſcourſe of the ſolidity of the reaſons on the oneſide, or on the other, I will produce thoſe that move me to ſuſpend my allowance of this deſign.

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The first is, that although I dare not subscribe to the opinion of those that require 16. inches Declivity in a mile to *Reno*, to prevent its deposing of Mud; yet would I not be the Author that should make a trial of it with so much hazard, for having to satisfie my self in some particulars caused a Level to be taken of the Rivers *L'amone*, *Senio*, and *Santerno*, by *Bernardino Aleotti*, we found that they have more Declivity by much than Artists require, as also the *Reno* hath from *la Botta de Ghislieri* to the Chappel of *Vigarano*, for in the space of four miles its Bottom-Line falleth five feet and five inches. So that I hold it greater prudence to depend upon that example, than to go contrary to a common opinion, especially since, that the effects caused by *Reno* it self do confirm me in the same, for when it was forsaken by the *Po*, after a few years, either because it had choaked up its Chanel with Sand, or because its too long journey did increase it, it also naturally turned aside, and took the way of the said *Po* towards *Stellata*. Nay, in those very years that it did run that way, it only began (as relations say) to make Breaches, an evident sign that it doth depose Sand, and raise its Bed; which agreeth with the testimony of some that were examined in the *Visitation* of the Publique Notary, who found great benefit by having Running Water, and some kind of passage for Boats, and yet nevertheless affirm that it for want of Running Water had made too high Stoppages and Shelfes of Sand; so that if it should be restored to the Course that it forsook, I much fear that after a short time, if not suddenly, it would leave it again.

The second I take from the observation of what happened to *Panaro*, when with so great applause of the *Ferarese*, it was brought by Cardinal *Serra* into the said Chanel of *Volana*; for that notwithstanding that it had Running Waters in much greater abundance than *Reno*; yet in the time that it continued in that Chanel it raised its Bed well neer five feet, as is to be seen below the Sluice made by Cardinal *Capponi* to his new Chanel; yea, the said Cardinal *Serra* who desired that this his undertaking should appear to have been of no danger nor damage, was constrained at its Overflowings, to give it Vent into *Sanmartina*, that it might not break in upon, and prejudice the City; which danger I should more fear from *Reno*, in regard it carrieth a greater abundance of Water and Sand.

Thirdly, I am much troubled (in the uncertainty of the success of the affair) at the great expence thereto required; For in regard I do not approve of letting it in, neer to the Fortresse, for many respects, and carrying it by *la Torre del Fondo* to the Mouth *de Masi*, it will take up eight miles of double Banks, a

thing not eaſie to be procured, by reaſon that the Grounds lie under Water; but from the Mouth *de Maſi* unto *Codigoro*, it would alſo be neceſſary to make new Scowrings of the Chanel; to the end, that the Water approaching (by wearing and carrying away the Earth on both ſhores, might make a Bed ſufficient for its Body, the depth made for *Panaro* not ſerving the turn, as I conceive; and if it ſhould ſuffice, when could the people of *Ferrara* hope to be re-imburſed and ſatisfied for the charge thereof?

Fourthly, it ſerves as an Argument with me, to ſee that the very individual perſons concerned in the Remotion or Diverſion of the ſaid Torrent, namely, the *Bologneſi* do not incline unto it, and that the whole City of *Ferrara*, even thoſe very perſons who at preſent receive damage by it, cannot indure to hear thereof. The reaſon that induceth theſe laſt named to be ſo averſe thereto, is, either becauſe that this undertaking will render the introduction of the Water of *Main*-Po more difficult; or becauſe they fear the danger thereof; The others decline the Project, either for that they know that *Reno* cannot long continue in that Courſe, or becauſe they fear that it is too much expoſed to thoſe mens revengeful Cutting of it who do not deſire it ſhould; and if a man have any other wayes, he ought, in my opinion, to forbear that, which to ſuch as ſtand in need of its Removal, is leſſe ſatisfactory, and to ſuch as oppoſe it, more prejudicial.

To conclude, I exceedingly honour the judgment of Cardinal *Capponi*, who having to his Natural Ability and Prudence added a particular Study, Obſervation, and Experience of theſe Waters for the ſpace of three years together, doth not think that *Reno* can go by *Volana*; to which agreeth the opinion of Cardinal S. *Marcello*, Legate of this City, of whom, for his exquiſite underſtanding, we ought to make great account. But if ever this ſhould be reſolved on, it would be materially neceſſary to unite the Quick and Running Waters of the little Chanel of *Cento*, of the Chanel *Navilio*, of *Guazzaloca*, and at its very beginning thoſe of *Dardagna*, which at preſent, is one of the Springs or Heads of *Panaro*, that ſo they might aſſiſt it in carrying its Sand, and the matter of its Muddineſs into the Sea; and then there would not fail to be a greater evacuation and ſcowring; but withall the Proprietors in the Iſlet of *San Giorgio* and of *Ferrara* muſt prepare themſelves to indure the inconveniences of Purlings or Sewings of the Water from the River thorow the Boggy Ground thereabouts.

I ſhould more eaſily incline therefore to carry it into *Main-Po* at *Stellata*, for the Reaſons that Cardinal *Capponi* moſt ingeniouſly enumerates in a ſhort, but well-grounded Tract of his: not becauſe

becauſe that indeed it would not both by Purlings and by Breaches occaſion ſome inconvenience; eſpecially, in the beginning: but becauſe I hold this for the incomodities of it, to be a far leſs evil than any of the reſt; and becauſe that by this means there is no occaſion given to them of *Ferrara*, to explain that they are deprived of the hope of ever ſeeing the *Po* again under the Walls of their City: To whom, where it may be done, it is but reaſon that ſatisfaction ſhould be given.

It is certain that *Po* was placed by Nature in the midſt of this great Valley made by the *Appennine* Hills, and by the Alps, to carry, as the Maſter-Drain to the Sea, that is the grand receptacle of all Waters; thoſe particular ſtreams which deſcend from them.

That the *Reno* by all Geographers, *Strabo*, *Pliny*, *Solinus*, *Mella*, and others is enumerated among the Rivers that fall into the ſaid *Po*.

That although *Po* ſhould of it ſelf change its courſe, yet would *Reno* go to look it out, if the works erected by humane induſtry did not obſtruct its paſſage; ſo that it neither is, nor ought to ſeem ſtrange, if one for the greater common good ſhould turn it into the ſame.

Now at *Stellata* it may go ſeveral waies into *Po*, as appeareth by the levels that were taken by my Order; of all which I ſhould beſt like the turning of it to *la Botta de' Ghiſlieri*, carrying it above *Bondeno* to the Church of *Gambarone*, or a little higher or lower, as ſhall be judged leaſt prejudicial, when it cometh to the execution, and this for two principal reaſons: The one becauſe that then it will run along by the confines of the Church Patrimony, without ſeparating *Ferrara* from the reſt of it; The other is, Becauſe the Line is ſhorter, and conſequently the fall greater; for that in a ſpace of ten miles and one third, it falleth twenty ſix feet, more by much than is required by Artiſts; and would go by places where it could do but little hurt, notwithſtanding that the perſons intereſſed ſtudy to amplifie it incredibly.

On the contrary, there are but onely two objections that are worthy to be examined; One, That the Drains and Ditches of S. *Bianca*, of the Chanel of *Cento*, and of *Burana*, and all thoſe others that enter into *Po*, do hinder this diverſion of *Reno*, by the encreaſing of the waters in the *Po*. The other is that *Po* riſing about the Tranſom of the *Pilaſter*-Sluice, very near 20 feet, the *Reno* would have no fall into the ſame; whereupon it would riſe to a terrible height, at which it would not be poſſible to make, or keep the Banks made; ſo that it would break out and drown the Meadowes, and cauſe miſchiefs, and damages unſpeakable and irreparable; as is evident by the experiment made upon

Panaro, which being confined between Banks, that it might go into *Po*, this not being neither in its greateſt excreſcenſe, it broke out into the territories of *Final*, and of *Ferrara*. And though that might be done, it would thereupon enſue, that there being let into the Chanel of *Po*, 2800. ſquare feet of water (for ſo much we account thoſe of *Reno* and *Panaro*, taken together in their greateſt heights) the ſuperficies of it would riſe at leaſt four feet, inſomuch that either it would be requiſite to raiſe its Banks all the way unto the Sea, to the ſame height, which the treaſures of the *Indies* would not ſuffice to effect; or elſe there would be a neceſſity of enduring exceſſive Breaches. To theſe two Heads are the Arguments reduced, which are largely amplified againſt our opinion; and I ſhall anſwer firſt to the laſt, as moſt material.

I ſay therefore, that there are three caſes to be conſidered: Firſt, *Po* high, and *Reno* low. Secondly, *Reno* high, and *Po* low. Thirdly, *Reno* and *Po* both high together.

As to the firſt and ſecond, there is no difficulty in them; for if *Po* ſhall not be at its greateſt height, *Reno* ſhall ever have a fall into it, and there ſhall need no humane Artifice about the Banks: And if *Reno* ſhall be low, *Po* ſhall regurgitate and flow up into the Chanel of it; and alſo from thence no inconvenience ſhall follow. The third remains, from which there are expected many miſchiefs; but it is a moſt undoubted truth, that the excreſcencies of *Reno*, as coming from the adjacent *Appennines* and Rains, are to continue but ſeven, or eight hours at moſt, and ſo would never, or very rarely happen to be at the ſame time with thoſe of *Po*, cauſed by the melting of the ſnowes of the Alps, at leaſt 400. miles diſtance from thence. But becauſe it ſometimes may happen, I reply, that when it cometh to paſs, *Reno* ſhall not go into *Po*, but it ſhall have allowed it one or two Vents; namely, into the Chanel of *Ferrara*, as it hath ever had; and into *Sanmartina*, where it runneth at preſent, and wherewith there is no doubt, but that the perſons concerned will be well pleaſed, it being a great benefit to them, to have the water over-flow their grounds once every four or five years, inſtead of ſeeing it anoy them continually. Yea, the Vent may be regulated, reſerving for it the Chanel in which *Reno* at preſent runneth; and inſtead of turning it by a Dam at *la Betta de Ghiſlieri*, perhaps, to turn it by help of ſtrong Sluices, that may upon all occaſions be opened and ſhut. And for my part, I do not queſtion but that the Proprietors themſelves in *Sanmartina* would make a Chanel for it; which receiving, and confining it in the time of the Vents, might carry the Sand into the *Po* of *Primaro*: Nor need there thence be feared any ſtoppage by Mud and Sand, ſince that it is ſuppoſed that there will but very ſeldom be any neceſſity of uſing it; ſo that

time

time would be allowed, upon occaſion, to ſcowr and cleanſe it.

And in this manner all thoſe Prodigies vaniſh that are raiſed with ſo much fear from the enterance of the Water of *Reno* ſwelled into *Po*, when it is high, to which there needeth no other anſwer; yet nevertheleſſe we do not take that quantity of Water, that is carried by *Reno*, and by *Panaro*, to be ſo great as is affirmed: For that P. D. *Benedetto Caſtelli* hath no leſſe accutely than accurately obſerved the meaſures of this kind, noting that the breadth and depth of a River is not enough to reſolve the queſtion truly, but that there is reſpect to be had to the velocity of the Waters, and the term of time, things hitherto not conſidered by the Skilful in theſe affairs; and therefore they are not able to ſay what quantity of Waters the ſaid Rivers carry, nor to conclude of the riſings that will follow thereupon. Nay, it is moſt certain, that if all the Rivers that fall into *Po*, which are above thirty, ſhould riſe at the rate that theſe compute *Reno* to do, an hundred feet of Banks would not ſuffice, and yet they have far fewer: So that this confirmes the Rule of R. P. D. *Benedetto*, namely, that the proportion of the height of the Water of *Reno* in *Reno* to the height of the Water of *Reno* in *Po*, is compounded of the proportion of the breadth of the Chanel of *Po* to that of *Reno*, and of the velocity of the Water of *Reno* in *Po* to the velocity of the Water of *Reno* in *Reno*; a manifeſt argument that there cannot in it, by this new augmentation of Waters follow any alteration that neceſſitates the raiſing of its Banks, as appeareth by the example of *Panaro*, which hath been ſo far from ſwelling *Po*, that it hath rather aſſwaged it, for it hath carried away many Shelfs and many Iſlets that had grown in its Bed, for want of Waters ſufficient to bear away the matter of Land-floods in ſo broad a Chanel; and as is learnt by the trial made by us in *Panaro* with the Water of *Burana*; for erecting in the River ſtanding marks, and ſhutting the ſaid Sluice, we could ſee no ſenſible abatement, nor much leſs after we had opened it ſenſible increaſment; by which we judge that the ſame is to ſucceed to *Po*, by letting in of *Reno*, *Burana* having greater proportion to *Panaro* than *Reno* to *Po*, conſidering the ſtate of thoſe Rivers in which the Obſervation was made. So that there is no longer any occaſion for thoſe great raiſings of Banks, and the danger of the ruptures as well of *Reno* as of *Po* do vaniſh, as alſo the fear leſt that the Sluices which empty into *Po* ſhould receive obſtruction: which if they ſhould, yet it would be over in a few hours. And as to the Breaches of *Panaro* which happened in 1623. I know not why, ſeeing it is confeſſed that the *Po* was not, at that time, at its height, one ſhould rather charge it

with

with the crime, than quit it thereof. The truth is, that the Bank was not made of proof, ſince that the ſame now continueth whole and good, and *Panaro* doth not break out; nay, there was, when it brake more than a foot and half of its Banks above the Water, and to ſpare; but it broke thorow by a Moles working, or by the hole of a Water-Rat, or ſome ſuch vermine; and by occaſion of the badneſs of the ſaid Banks, as I finde by the teſtimony of ſome witneſſes examined by my command, that I might know the truth thereof. Nor can I here forbear to ſay, that it would be better, if in ſuch matters men were more candid and ſincere. But to ſecure our ſelves nevertheleſſe, to the utmoſt of our power, from ſuch like Breaches which may happen at the firſt, by reaſon of the newneſſe of the Banks, I preſuppoſe that from *Po* unto the place whence *Reno* is cut, there ought to be a high and thick Fence made with its Banks, ſo that there would be no cauſe to fear any whatſoever acceſſions of Water, although that concurrence of three Rivers, which was by ſome more ingeniouſly aggravated than faithfully ſtated by that which was ſaid above were true; to whom I think not my ſelf bound to make any farther reply, neither to thoſe who ſay that *Po* will aſcend upwards into *Reno*, ſince that theſe are the ſame perſons who would introduce a ſmall branch of the ſaid *Po* into the Chanel of *Ferrara*, that ſo it may conveigh to the Sea, not *Reno* onely, but alſo all the other Brooks of which we complained; and becauſe that withal it is impoſſible, that a River ſo capacious as *Po* ſhould be incommoded by a Torrent, that, as I may ſay, hath no proportion to it.

I come now to the buſineſſe of the Ditches and Draines; and as to the Conveyance of *Burana*, it hath heretofore been debated to turn it into *Marn-Po*, ſo that in this caſe it will receive no harm, and though it were not removed, yet would it by a Trench under ground purſue the courſe that it now holdeth, and alſo would be able to diſ-imbogue again into the ſaid new Chanel of *Reno*, which conforming to the ſuperficies of the Water of *Po*, would continue at a lower level than that which *Panara* had when it came to *Ferrara*, into which *Burana* did nevertheleſſe empty it ſelf for ſome time.

The Conveyance or Drain of *Santa Bianca*, and the little Chanel of *Cento* may alſo empty themſelves by two ſubterranean Trenches, without any prejudice where they run at preſent, or without any more works of that nature, they may be turned into the ſaid new Chanel, although with ſomewhat more of inconvenience; and withall, the Chanel of *Ferrara*, left dry, would be a ſufficient receptacle for any other Sewer or Drain whatſoever, that ſhould remain there.

All

All which Operations might be brought to perfection with 150. thousand Crowns, well and faithfully laid out; which summ the *Bologneſi* will not be unwilling to provide; beſides that thoſe *Ferrareſi* ought to contribute to it, who ſhall partake of the benefit.

Let me be permitted in this place to propoſe a thing which I have thought of, and which peradventure might occaſion two benefits at once, although it be not wholly new. It was in the time of *Pope Paul* V. propounded by one *Creſcenzio* an Ingineer, to cut the *Main*-*Po*, above *le Papozze*; and having made a ſufficient evacuation to derive the water thereof into the *Po* of *Adriano*, and ſo to procure it to be Navigable, which was not at that time effected, either by reaſon of the oppoſitions of thoſe, whoſe poſſeſſions were to be cut thorow, or by reaſon of the great ſum of money that was neceſſary for the effecting of it; But in viewing thoſe Rivers, we have obſerved, that the ſedge cutting might eaſily be made below *le Papozze*, in digging thorow the Bank called *Santa Maria*, & drawing a Trench of the bigneſs that skilful Artiſts ſhall judge meet unto the *Po* * of *Ariano*, below the *Secche* of the ſaid S. *Maria*; which as being a work of not above 160. Perches in length, would be finiſhed with onely 12000. Crowns.

* Of *Adriano.*

Firſt; it is to be believed, that the waters running that way, would not fail to open that Mouth into the Sea, which at preſent is almoſt choakt up by the Shelf of Sand, which the new Mouth of *Ponte Virro* hath brought thither; and that it would again bring into uſe the Port *Goro*, and its Navigation.

And haply experience might teach us, that the ſuperficies of *Po* might come to fall by this aſſwagement of Water, ſo that the acceſſion of *Reno* would queſtionleſs make no riſing in it: Whereupon, if it ſhould ſo fall out, thoſe Princes would have no reaſon to complain; who ſeem to queſtion, leſt by this new acceſſion of water into *Po*, the Sluices might be endangered. Which I thought not fit to omit to repreſent to your Lordſhip; not, that I propoſe it to you as a thing abſolutely certain, but that you might, if you ſo pleaſed, lay it before perſons whoſe judgements are approved in theſe affairs.

I return now from where I degreſt, and affirm it as indubitable, that *Reno* neither can, nor ought to continue longer where it at this day is; and that it cannot go into any other place but that, whither *Cardinal Capponi* deſigned to carry it, and which at preſent pleaſeth me better than any other; or into *Volana*, whence it was taken away; the vigilance of Men being able to obviate part of thoſe miſchiefs, which it may do there.

But from its Removal, beſides the alleviation of the harm which

which by it ſelf is cauſed, there would alſo reſult the diminution of that which is occaſioned by the other Brooks, to the right hand of the *Po* of *Argenta*; foraſmuch as the ſaid *Po* wanting all the water of *Reno*, it would of neceſſity come to ebb in ſuch manner, that the Valleys would have a greater Fall into the ſame, and conſequently it would take in, and ſwallow greater abundance of water; and by this means the Ditches and Draines of the Up-Lands would likewiſe more eaſily Fall into them; eſpecially if the ſcouring of *Zenzalino* were brought to perfection, by which the waters of *Marrara* would fall into *Marmorta*: And if alſo that of *Baſtia* were enlarged, and finiſhed, by which there might enter as much water into the ſaid Po of *Argenta*, as is taken from it by the removal of *Reno*; although that by that meanes the water of the Valleys would aſſwage double: Nor would the people of *Argenta*, the Iſles of S. *Giorgio*, and *Comacchio* have any cauſe to complain; for that there would not be given to them more water than was taken away: Nay ſometimes whereas they had Muddy waters, they would have clear; nor need they to fear any riſing: And furthermore, by this means a very great quantity of ground would be reſtored to culture; For the effecting of all which, the ſumm of 50. thouſand Crowns would go very far, and would ſerve the turn at preſent touching thoſe Brooks, carrying them a little farther in the mean time, to fill up the greater cavities of the Valleys, that we might not enter upon a vaſter and harder work, that would bring with it the difficulties of other operations, and ſo would hinder the benefit which theſe people expect from the paternal charity of His Holineſs.

TO

TO
The Right Honourable,
MONSIGNORE
D. Ferrante Ceſarini.

MY Treatiſe of the MENSURATION of RUNNING WATERS, Right Honourable, and moſt Noble Sir, hath not a greater Prerogative than its having been the production of the command of Pope *Urban* VIII. when His Holineſs was pleaſed to enjoyn me to go with *Monſignore Corſini*, in the Viſitation that was impoſed upon him in the year 1625. of the Waters of *Ferrara*, *Bologna*, *Romagna*, and *Romagnola*; for that, on that occaſion applying my whole Study to my ſervice and duty, I publiſhed in that Treatiſe ſome particulars till then not rightly underſtood and conſidered (that I knew) by any one; although they be in themſelves moſt important, and of extraordinary conſequence. Yet I muſt render thanks to Your Lordſhip for the honour you have done to that my Tract; but wiſh withal, that your Eſteem of it may not prejudice the univerſal Eſteem that the World hath of Your Honours moſt refined judgement.

As to that Point which I touch upon in the Concluſion, namely, That the conſideration of the Velocity of Running Water ſupplyeth the conſideration of the * Length omitted in the common way of meaſuring Running Waters; Your Lordſhip having commanded me that in favour of *Practiſe*, and for the perfect diſcovery of the diſorder that commonly happeneth now adayes in the diſtribution of the Waters of Fountains, I ſhould demonſtrate that the knowledge of the Velocity ſerveth for the finding of the Length: I have thought fit to ſatisfie your Command by relating a Fable; which, if I do not deceive my ſelf, will make out to us the truth thereof; inſomuch that the reſt of my Treatiſe ſhall thereby alſo become more manifeſt and intelligible, even to

* Larghezza, but miſprinted.

thoſe who finde therein ſome kinde of obſcurity.

In the dayes of yore, before that the admirable Art of Weaving was in uſe, there was found in *Perſia* a vaſt and unvaluable Treaſure, which conſiſted in an huge multitude of pieces of Ermeſin, or Damask, I know not whether; which, as I take it, amounted to near two thouſand pieces; which were of ſuch a nature, that though their Breadth and Thickneſs were finite and determinate, as they uſe to be at this day; yet nevertheleſs, their Length was in a certain ſenſe infinite, for that thoſe two thouſand pieces, day and night without ceaſing, iſſued out with their ends at ſuch a rate, that of each piece there iſſued 100. Ells a day, from a deep and dark Cave, conſecrated by the Superſtition of thoſe people, to the fabulous *Arachne*. In thoſe innocent and early times (I take it to have been, in that ſo much applauded and deſired Golden age) it was left to the liberty of any one, to cut off of thoſe pieces what quantity they pleaſed without any difficulty: But that felicity decaying and degenerating, which was altogether ignorant of *Meum* and *Tuum*; terms certainly moſt pernicious, the Original of all evils, and cauſe of all diſcords; there were by thoſe people ſtrong and vigilant Guards placed upon the Cave, who reſolved to make merchandize of the Stuffes; and in this manner they began to ſet a price upon that ineſtimable Treaſure, ſelling the propriety in thoſe pieces to divers Merchants; to ſome they ſold a right in one, to ſome in two, and to ſome in more. But that which was the worſt of all, There was found out by the inſatiable avarice of theſe men crafty inventions to deceive the Merchants alſo; who came to buy the aforeſaid commodity, and to make themſelves Maſters, ſome of one ſome of two, and ſome of more ends of thoſe pieces of ſtuff; and in particular, there were certain ingenuous Machines placed in the more ſecret places of the Cave, with which at the pleaſure of the Guards, they did retard the velocity of thoſe Stuffs, in their iſſuing out of the Cave; inſomuch, that he who ought to have had 100. Ells of Stuff in a day, had not above 50, and he who ſhould have had 400, enjoyed the benefit of 50. onely; and ſo all the reſt were defrauded of their Rights, the ſurpluſage being ſold, appropriated, and ſhared at the will of the corrupt Officers: So that the buſineſs was without all order or juſtice, inſomuch that the Goddeſs *Arachne* being diſpleaſed at thoſe people, deprived every one of their benefit, and with a dreadful Earthquake for ever cloſing the mouth of the Cave, in puniſhment of ſo much impiety and malice: Nor did it avail them to excuſe themſelves, by ſaying that they allowed the Buyer the Breadth and Thickneſs bargained for; and that of the Length, which was infinite,

there

there could no account be kept: For the wise and prudent Priest of the Sacred *Grotto* answered, That the deceit lay in the length, which they were defrauded of, in that the velocity of the stuffe was retarded, as it issued out of the Cave: and although the total length of the Piece was infinite, for that it never ceased coming forth, and so was not to be computed; yet nevertheless its length considered, part by part, as it came out of the Cave, and was bargained for, continued still finite, and might be one while greater, and another while lesser, according as the Piece was constituted in greater or lesser velocity; and he added withall, that exact Justice required, that when they sold a piece of stuff, and the propriety or dominion therein, they ought not only to have ascertained the breadth and thickneſse of the Piece, but also to have determined the length, determining its velocity.

The same disorder and confusion, that was represented in the Fable, doth come to passe in the History of the Distribution of the Waters of Conduits and Fountains, seeing that they are sold and bought, having regard only to the two Dimensions, I mean of Breadth and Height of the Mouth that dischargeth the Water; and to remedy such an inconvenience, it is necessary to determine the length in the velocity; for never shall we be able to make a guesse at the quantity of the Body of Running VVater, with the two Dimensions only of Breadth and Height, without Length.

And to the end, that the whole business may be reduced to a most easie practice, by which the waters of Aqueducts may be bought and sold justly, and with measures alwayes exact and constant.

First, the quantity of the Water ought diligently to be examined, which the whole principal Pipe dischargeth in a time certain, as for instance, in an hour, in half an hour, or in a lesse interval of time, (for knowing which I have a most exact and easie Rule) and finding that the whole principal pipe dischargeth *v. g.* a thousand Tuns of Water in the space of one or more hours, in selling of this water, it ought not to be uttered by the ordinary and false measure, but the distribution is to be made with agreement to give and maintain to the buyer ten or twenty, or a greater number of Tuns, as the bargain shall be made, in the space of an hour, or of some other set and determinate time. And here I adde, that if I were to undertake to make such an adjustment, I would make use of a way to divide and measure the time with such accurateneſse, that the space of an hour should be divided into four, six, or eight thousand parts

without the least errour; which Rule was taught me by my Master *Sign. Galileo Galilæi*, Chief Philosopher to the most Serene *Grand Duke* of *Tuscany*. And this way will serve easily and admirably to our purpose and occasion; so that we shall thereby be able to know how many Quarts of Water an Aqueduct will discharge in a given time of hours, moneths, or years. And in this manner we may constitute a Cock that shall discharge a certain and determinate quantity of water in a time given.

And becaufe daily experience shews us, that the Springs of Aqueducts do not maintain them alwayes equally high, and full of Water, but that sometimes they increase, and sometimes decrease, which accident might possibly procure some difficulty in our distribution; Therefore, to the end that all manner of scruple may be removed, I conceive that it would be convenient to provide a Cistern, according to the occasion, into which there might alwayes fall one certain quantity of water, which should not be greater than that which the principal pipe dischargeth in times of drought, when the Springs are bare of water, that so in this Cistern the water might alwayes keep at one constant height. Then to the Cistern so prepared we are to fasten the Cocks of particular persons to whom the Water is sold by the Reverend Apostolique Chamber, according to what hath been observed before; and that quantity of Water which remaineth over and above, is to be discharged into another Cistern, in which the Cocks of the Waters for publick services, and of those which people buy upon particular occasions are to be placed. And when the businesse shall have been brought to this passe, there will likewise a remedy be found to the so many disorders that continually happen; of which, for brevity sake, I will instance in but four only, which concern both publique and private benefit, as being, in my judgment, the most enormous and intolerable.

The first inconvenience is, that in the common way of measuring, dispensing, and selling the Waters of Aqueducts, it is not understood, neither by the Buyer nor Seller, what the quantity truly is that is bought and sold; nor could I ever meet with any either Enginer or Architect, or Artist, or other that was able to decypher to me what one, or two, or ten inches of water was. But by our above declared Rule, for dispensing the Waters of Aqueducts we may very easily know the true quantity of Water that is bought or sold, as that it is so many Tuns an hour, so many a day, so many in a year, &c.

The second disorder that happeneth at present, in the distributing

bution of Aqueducts is, that as the buſineſſe is now governed, it lieth in the power of a ſordid Maſon to take unjuſtly from one, and give undeſervedly to another more or leſſe Water than belongeth to them of right: And I have ſeen it done, of my own experience. But in our way of meaſuring and diſtributing Waters, there can no fraud be committed; and putting the caſe that they ſhould be committed, its an eaſie matter to know it, and amend it, by repairing to the Tribunal appointed.

Thirdly, it happens very often, (and we have examples thereof both antient and modern) that in diſpenſing the Water after the common and vulgar way; there is ſometimes more Water diſpended than there is in the Regiſter, in which there will be regiſtred, as they ſay, two hundred inches (for example) and there will be diſpenſed two hundred and fifty inches, or more. Which paſſage happened in the time of *Nerva* the Emperour, as *Giulio Frontino* writes, in his 2. Book, *De Aquaductibus Urbis Romæ*, where he obſerveth that they had *in Commentariis* 12755. *Quinaries* of Water; and found that they diſpenſed 14018. *Quinaries*. And the like Errour hath continued, and is in uſe alſo modernly until our times. But if our Rule ſhall be obſerved, we ſhall incur no ſuch diſorder, nay there will alwayes be given to every one his ſhare, according to the holy end of exact juſtice, which *dat unicuique quod ſuum eſt*. As on the contrary, it is manifeſt, that His Divine Majeſty hateth and abominateth *Pondus & pondus, Menſura & menſura*, as the Holy Ghoſt ſpeaketh by the mouth of *Solomon* in the *Proverbs*, *Chap.* 20. *Pondus & Pondus, Menſura & Menſura, utrumque abominabile eſt apud Deum*. And therefore who is it that ſeeth not that the way of dividing and meaſuring of VVaters commonly uſed, is expreſly againſt the Law of God. Since that thereby the ſame meaſure is made ſometimes greater, and ſometimes leſſer; A diſorder ſo enormous and execrable, that I ſhall take the boldneſs to ſay, that for this ſole reſpect it ought to be condemned and prohibited likewiſe by human Law, which ſhould Enact that in this buſineſs there ſhould be imployed either this our Rule, or ſome other that is more exquiſite and practicable, whereby the meaſure might keep one conſtant and determinate tenor, as we make it, and not, as it is now, to make *Pondus & Pondus, Menſura & Menſura*.

And this is all that I had to offer to Your moſt Illuſtrious Lordſhip, in obedience to your commands, reſerving to my ſelf the giving of a more exact account of this my invention, when the occaſion ſhall offer, of reducing to practice ſo holy, juſt, and neceſſary

necessary a reformation of the Measure of Running Waters and of Aqueducts in particular: which Rule may also be of great benefit in the division of the greater Waters to over-flow Grounds, and for other uses: I humbly bow,

Your Most Devoted,

and

Most Obliged Servant,

D. Benedetto Castelli, *Abb. Casin.*

FINIS.

A TABLE

Of the most observable matters in this Treatise of the MENSURATION of RUNNING WATERS.

A

ABatements *of a River in different and unequal Diversions, is always equal, which is proved with* 100. Syphons. *Page* 75

Arno *River when it riseth upon a Land-Flood near the Sea one third of a Brace, it riseth about* Pisa 6. *or* 7. *Braces.* 82

B

Banks near to the Sea lower, than far from thence. Corollary XIV. 16

Brent *River diverted from the Lake of* Venice, *and its effects.* 64

Brent *supposed insufficient to remedy the inconveniences of the Lake, and the falsity of that supposition.* 67

Brent, *and its benefits in the Lake.* 70

Its Deposition of Sand *in the Lake, how great it is.* 78, 79

Bridges over Rivers, and how they are to be made. Appendix VIII. 20

Burana *River, its rising, and falling in* Panaro. 110

C

Castelli *applyed himself to this Study by Order of* Urban VIII. 2

Chanel of Navigation *in the Valleys of* Bologna, *and its inconveniences.* 99

Carried into the Po *of* Ferrara, *and its benefits* ibid.

Ciampoli *a lover of these Observations of Waters.* 3

D

Difficulty of this business of Measuring Waters. 2

Disorders that happen in the distribution of the Waters of Aqueducts, and their remedies. 113

Distribution of the Waters of Fountains, and Aqueducts. Appendix X. 22

Distribution of Water to over-flow Grounds. Appendix XI. 23, 69, 70

Diversion of Reno *and other Brooks of* Romagna, *advised by* P. Spernazzati *to what end it was.* 100

Drains and Ditches, the benefit they receive by cutting away the Weeds and Reeds. Appendix IX. 21

Drains and Sewers obstructed, in the Diversion of Reno *into* Main Po, *and a remedy for the same.* 110

E

Engineers unversed in the matters of Waters. 2

Erour found in the common way of Measuring Running Waters. 68, 69

Errour in deriving the Water of Acqua Paola. *Appendix* II. 17, 18

Errour of Bartolotti. 86, 87
Errours of Engineers in the Derivation of Chanels. Corollary XII. 12
Errour of Engineers in Measuring of Reno *in* Po. *Appendix* III. ibid.
Errour of other Engineers, contrary to the precedent. Appendix IV. Ibid.
Errour of Giovanni Fontana *in Measuring Waters. Corollary* XI. 9
Errour of Giulio Frontino *in Measuring the Waters of Aqueducts. Appendix* I. 17
Errours committed in cutting the Bank at Bondeno, *in the swellings of* Po: *Corollary* XIII. 81

F

Fenns Pontine, *Drained by Pope* Sixtus Quintus, *with vast expence.* 92
The ruine and miscarriage thereof. 93
Tardity of the principal Chanel that Drains them, cause of the Drowning. ibid.
They are obstructed by the Fishing-Weers, which swell the River. 94
waters of Fiume Sisto, *which flow in great abundance into the* Evacuator *of the said Fenns.* 94, 95
Remedies to the disorders of those Fenns. 95, 96
Fontana Giovanni, *his errours in Measuring Waters. Corollary* XI. 9
Fiume Morto, *whether it ought to fall into the Sea, or into* Serchio, 79
Let into Serchio *and its inconveniences.* 79, 80
The dangerous rising of its Waters, when to be expected. 81
Its inconveniences when it is higher in level than Serchio, *and why it riseth most On the Sea-coasts, at such time as the Winds make the Sea to swell.* 83

G

Galilæo Galilæi, *honourably mentioned.* Page 2, 28
His Rule for measuring the time. 49

H

Height, vide *Quick*
Heights different, made by the same stream of a Brook or Torrent, according to the divers Velocities in the entrance of the River. Corollary I. 6
Heights different, made by the Torrent in the River, according to the different heights of the River. Corollary II. ibid.

K

Knowledge of Motion how much it importeth. 1

L

Lake of Perugia, *and the Observation made on it. Appendix* XII. 42
Lake of Thrasimenus *and Considerations upon it, a Letter written to* Sig. Galilæo Galilæi. 28
Lake of Venice, *and Considerations upon it.* 63, 73
Low Waters which let the bottom of it be discovered. 64
The stoppage and choaking of the Ports, a main cause of the disorders of the Lake, and the grand remedy to those disorders what it is. 66
Lakes and Meers along the Sea-coasts, and the causes thereof. 65
Length of Waters, how it is to be Measured. 70

M

Measure and Distributions of Waters. Appendix V. 18

Measure

The Table.

Measure of Rivers that fall into others difficult. Coroll. X. 9
Measure of the Running Water of a Chanel of an height known by a Regulator *of a Measure given, in a time assigned. Proposition* I. *Problem* I. 50
Measure of the Water of any River, of any greatness, in a time given. Proposition V. *Problem* III. 60
Measure that shewes how much Water a River dischargeth in a time given. 48
Mole-holes,
Motion the principal subject of Philosophy. 1
Mud. Vide *Sand.*

N

Navigation from Bologna *to* Ferrara, *is become impossible, till such time as* Reno *be diverted.* 101
Navigation in the Lake of Venice *endangered, and how restored.* 65, 70

P

Perpendicularity of the Banks of the River, to the upper superficies of it. 37
Perpendicularity of the Banks to the bottom. 37
Perugia. Vide *Lake.*
Pontine. Vide *Fenns.*
Ports of Venice, Malamocco, Bondolo, *and* Chiozza, *choaked up for want of Water in the Lake.* 65
Proportions of unequal Sections of equal Velocity, and of equal Sections of unequal Velocity. Axiome IV. *and* V. 38
Proportions of equal and unequal quantities of Water, which pass by the Sections of different Rivers. Proposition II. 39
Proportions of unequal Sections that in equal times discharge equal quantities of Water. Proposition III. 41
Proportion wherewith one River falling into another, varieth in height. Proposition IV. 44
Proportion of the Water discharged by a River in the time of Flood, to the Water discharged in an equal time by the said River, before or after the Flood. Proposition V. 44
Proportion of the Heights made by two equal Brooks or Streams falling into the same River. Proposition VI. 45
Proportion of the Water which a River dischargeth encreasing in Quick-height by the addition of new Water, to that which it dischargeth after the encrease is made. Proposition IV. *Theor.* II. 54
Proportion of a River when high, to it self when low. Coroll. I. 55

Q

Quantity of Running Waters is never certain, if with the Vulgar way of Measuring them, their Velocities be not considered. 32
Quantities of Waters which are discharged by a River, answer in equality to the Velocities and times in which they are discharged. Axiome I, II, III. 38
Quick-Height *of a River, what it is. Definition* V. 48

R

Reason of the Proverb, Take heed of the still Waters. *Coroll.* VI. 7
Reasons of Monsignore Corsini *against the diversion of* Reno *into the* Po *of* Volano. 105
Reasons of Cardinal Capponi *and* Monsig. Corsini, *for the turning of* Reno *into Main* Po. 106

The Table.

Two objections on the contrary, and answers to them. 104 & 105
What ought to be the proportion of the Heights of Reno *in* Reno, *and of* Reno *in* Po. 110
Regulator what it is. Definition IV. 48
Relation of the Waters of Bologna *and* Ferrara, *by* Monsignore Corsini. 100
Reno *in the Valleys, and its bad effects.* 100, 101
Two wayes to divert it. 103
The facility and utility of those wayes. Ibid.
The difficulties objected. 104
Reply to Bartolotti *touching the dangers of turning* Fiume Morto *into* Serchio. 83
Retardment of the course of a River caused by its Banks. Appendix VII. 19
Risings made by Flood-Gates but small. Appendix XIII. 26
Rivers that are shallow swell much upon small showers, such as are deep rise but little upon great Floods. Corollary III. 6
Rivers the higher they are, the swifter. Ibid.
Rivers the higher they are, the lesse they encrease upon Floods. 49
Rivers when they are to have equal and when like Velocity. Ibid.
Rivers in falling into the Sea, form a Shelf of Sand called Cavallo. 65
Five Rivers to be diverted from the Lake of Venice, *and the inconveniences that would ensue thereupon.* 74, 75
A River of Quick-height, and Velocity in its Regulator being given, if the Height be redoubled by new Water, it redoubleth also in Velocity. Proposition II. *Theorem* I. 51
Keepeth the proportion of the heights, to the Velocities. Corollary 52

S

Sand and Mud that entereth into the Lake of Venice, *and the way to examine it.* 76
Seas agitated and driven by the Winds stop up the Ports. 64, 65
Sections of a River what they are. Definition I. 37
Sections equally swift what they are. Definition II. Ibid.
Sections of a River being given, to conceive others equal to them, of different breadth, height and Velocity. Petition. 38
Sections of the same River, and their Proportions to their Velocities. Coroll. I. 42
Sections of a River discharge in any whatsoever place of the said River, equal quantities of Water in equal times. Proposition I. 39
Sile *River what mischiefes it threatneth, diverted from the Lake.* 74
Spirtings of Waters grow bigger the higher they go. Coroll. XVI. 16
Streams of Rivers how they encrease and vary. Coroll. I. 6
Streams retarded, and the effects thereof. Coroll. IX. 8

T

Table of the Heights, Additions, and Quantities of Waters, and its use. 56
Thrasimenus. Vide *Lake.*
Time how its measured in these Operations of the Waters. 49
Torrents encrease at the encreasing of a River, though they carry no more Water than before: Coroll. IV. 6
Torrents when they depose and carry away the Sand. Coroll. V. 7
Torrents and their effects in a River. 6, 7
Torrents that fall into the Valleys, or into Po *of* Volano, *and their mischiefs prevented, by the diverting of* Reno *into* Main Po. 100
Tyber and the causes of its inundations. Coroll. VIII. 8

Val-

The Table.

V

Valleys of Bologna *and* Ferrara, *their inundations and disorders, whence they proceed.* 97
Velocity of the Water shewn by several Examples. 3
Its proportion to the Measure. 5
Velocities equal, what they are. 47
Velocities like, what they are. 47, 48
Velocities of Water known, how they help us in finding the Lengths. 113
A Fable to explain the truth thereof. Ibid.
Venice. Vide *Lake.*
Vse of the Regulator *in measuring great Rivers. Consideration I.* 60

W

Waters falling, why they disgross. Coroll. XVI. 16
Waters, how the Length of them is Measured. 70
Waters that are imployed to flow Grounds, how they are to be distributed. 19, 53, 54
Waters to be carryed in Pipes, to serve Aquaducts and Conduits, how they are to be Measured. 115, 116
Way to know the rising of Lakes by Raines. 28
Way of the Vulgar to Measure the Waters of Rivers. 68
Wind Gun, and Portable Fountain of Vincenzo Vincenti *of* Urbin. 11
Windes contrary, retard, and make Rivers encrease. Coroll. VII. 8

The End of the Table of the Second Part of the First TOME.